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Coastal and Hydraulics Laboratory

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Monitoring Completed Navigation Projects Program

Periodic Inspections of Cleveland Harbor East Breakwater, Ohio, and Burns Harbor North Breakwater, Indiana

Glenn B. Myrick, Jeffrey A. Melby, and Elizabeth C. Burg

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Abstract

Monitoring Completed Navigation Projects (MCNP) Program evaluates the structural and functional performance of existing navigation structures. Under Periodic Inspections, aerial photography, ground-truth surveys, walking inspections, photogrammetry, and lidar elevation data are used to periodically assess the structural conditions of selected structures. A database of these structures is being compiled for asset management and other purposes.

Cleveland Harbor East Breakwater, OH, has sustained extensive damage since its construction in 1915. The Breakwater has had an extensive repair history, including a major rehabilitation in 1979–80 involving the placement of 2-ton dolosse on the lakeward slope and crest of the easterly 4,400 feet (ft). Some failed and were replaced with 4-ton dolosse. Other repairs took place in 1986, 1989, 1991, and 2001 on the nondolos sections.

Burns Harbor North Breakwater, IN, is a 4,640 ft rubble-mound structure constructed in 1969. The Breakwater has required extensive maintenance including the addition of 290 kilotons of stone through 1989. A submerged reef was constructed between 1995 and 1998, 75 ft lakeward of the Breakwater, to reduce wave energy reaching the structure.

Records indicate that 1,128 broken and/or cracked dolosse, and 282 damaged armor stones, were documented during the 2006 Periodic Inspections of Cleveland Harbor East Breakwater and Burns Harbor North Breakwater, respectively. This interim data report contains a precise record of dolos and stone armor damage existing in July 2006 on these structures. A comprehensive analysis and technical report correlating this damage with storm and water level conditions will be published at a later date as subsequent additional field data are obtained at these two Great Lakes breakwaters.

Contents

Figures and Tables

Figures

Tables

Preface

This interim data report describes procedures and results of a periodic inspection during July 2006 of dolos concrete armor units on the Cleveland Harbor East Breakwater, Cleveland, OH, and of stone armor units on the Burns Harbor North Breakwater, Portage, IN. This report contains a precise record of dolos and stone armor damage existing in July 2006. A comprehensive analysis and technical report correlating this damage with storm and water level conditions will be published at a later date as subsequent additional field data are obtained at these two Great Lakes breakwaters. The study was performed by the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), for Headquarters, U.S. Army Corps of Engineers (HQUSACE).

The study reported herein was conducted under the Periodic Inspections work unit of the Monitoring Completed Navigation Projects (MCNP) program. MCNP is one of the USACE Navigation Programs. HQUSACE administers the overall program, and CHL manages the program. Principal investigator for the Periodic Inspections work unit at the time of this study was Dr. Jeffrey A. Melby, CHL. The Program Manager for the MCNP Program is Dr. Lyndell Z. Hales, CHL. Points-of-contact at the U.S. Army Corps of Engineers (USACE) Buffalo District (CELRB) for Cleveland Harbor are Shanon A. Chader and Michael C. Mohr. Tim Kroll is the point-of-contact for the USACE Chicago District (CELRC) for Burns Harbor.

CELRB provided ground surveys for both harbor breakwaters. Aerial photography and lidar elevation data were provided by the Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX), Stennis Space Center, MS.

In July 2006, Chader and Mohr and Glenn B. Myrick and Elizabeth C. Burg, CHL, conducted a walking inspection of the Cleveland Harbor East Breakwater. Dennis Rimmer, CELRB, provided boating support for the Cleveland inspection. In August 2006, Andrew R. Benziger, Mike Fornak, and Andrew Montez, CELRC, along with Myrick and Burg, conducted a walking inspection of Burns Harbor North Breakwater. Melvin McLaurin, CELRC, provided boat support for the Burns Harbor North Breakwater inspection.

This study was performed under the general supervision of Thomas W. Richardson, former Director, CHL. Direct supervision of this project was provided by José E. Sánchez, former Chief, Harbors, Entrances, and Structures Branch (HESB), CHL.

During preparation and publication of this report, José E. Sánchez was Director, CHL; Dr. Jacqueline S. Pettway was Chief, Navigation Division (ND), CHL; Dr. Donald L. Ward was former Acting Chief, HESB, ND; and James D. Gutshall, was Chief, HESB, ND. Program Monitor for the MCNP program was Jeffrey A. McKee, Chief, Navigation Branch, HQUSACE.

At the time of publication of this report, LTC John T. Tucker III was Acting Commander of ERDC. Dr. Jeffery Holland was Director.

Unit Conversion Factors

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
feet	0.3048	meters
inches	2.54	centimeters
miles (U.S. statute)	1.609347	kilometers
pounds (mass)	0.45359237	kilograms
tons (2,000 pounds, mass)	907.1847	kilograms
tons (2,000 pounds, mass)	0.9071847	megagrams

1 Introduction

1.1 Monitoring Completed Navigation Projects (MCNP) program

The goal of the MCNP program (formerly Monitoring Completed Coastal Projects [MCCP] program) is the advancement of coastal and hydraulic engineering technology. The program is designed to determine how well projects are accomplishing their purpose and how well they are resisting attacks by their physical environment. These determinations, combined with concepts and understanding already available, can (a) lead to the creation of more accurate and economical engineering solutions to coastal and hydraulic problems, (b) strengthen and improve design criteria and methodology, (c) improve construction practices and cost-effectiveness, and (d) improve operations and maintenance techniques. Additionally, the MCNP program will identify where current technology is inadequate or where additional research is required.

USACE in 1978 established an ad hoc committee of engineers and scientists to develop direction for the MCNP program. The committee formulated the objectives of the program, developed its operational philosophy, recommended its funding level, and established criteria and procedures for project selection. A significant result of their efforts was a prioritized listing of problem areas to be addressed. This is essentially a listing of the areas of interest of the program.

USACE offices are invited to nominate projects for inclusion in the MCNP program as funds become available. The MCNP program is governed by Engineer Regulation (ER) 1110-2-8151 (USACE 1997). A selection committee reviews and prioritizes the nominated projects on criteria established in the ER. The prioritized list is reviewed by the Program Monitor at HQUSACE. Final selection is based on this prioritized list, national priorities, and available funding.

The MCNP program is managed by ERDC, CHL, with guidance from HQUSACE. An individual monitoring project is a cooperative effort between the submitting USACE District and/or Division office and CHL.

1.2 Work unit objective and monitoring approach

The Periodic Inspections work unit was initiated in 1993 to provide long-term structural performance monitoring. Sites for periodic inspection are selected from previous MCCP or MCNP projects or based on the site's unique design features. Normally, sites selected for inclusion in the Periodic Inspections work unit have an intensive baseline survey. The structures are then monitored periodically, based on prioritized needs and funding, and evaluated for structural changes. A database of periodic inspections information is available that includes data that have been collected over several years through the Periodic Inspections work unit.

This interim data report describes procedures and results of a periodic inspection during July 2006 of dolos concrete armor units on the Cleveland Harbor East Breakwater, Cleveland, OH, and of stone armor units on the Burns Harbor North Breakwater, Portage, IN. This report contains a precise record of dolos and stone armor damage existing in July 2006. A comprehensive analysis and technical report correlating this damage with storm and water level conditions will be published at a later date as subsequent additional field data are obtained at these two Great Lakes breakwaters.

Traditional means of evaluations have included aerial photography and photogrammetry of above-water conditions of structures, in coordination with ground-truth surveys and detailed walking inspections. Due to funding constraints, photogrammetry was not performed for the Cleveland Harbor East Breakwater or the Burns Harbor North Breakwater during the 2006 inspections but was replaced with lidar technology. Lidar technology incorporates other advantages over photogrammetry (described in detail later in this report). Only the dolos concrete armor unit section of the Cleveland Harbor East Breakwater and the Burns Harbor North Breakwater, which is entirely armored with stone units, were included in this data acquisition,.

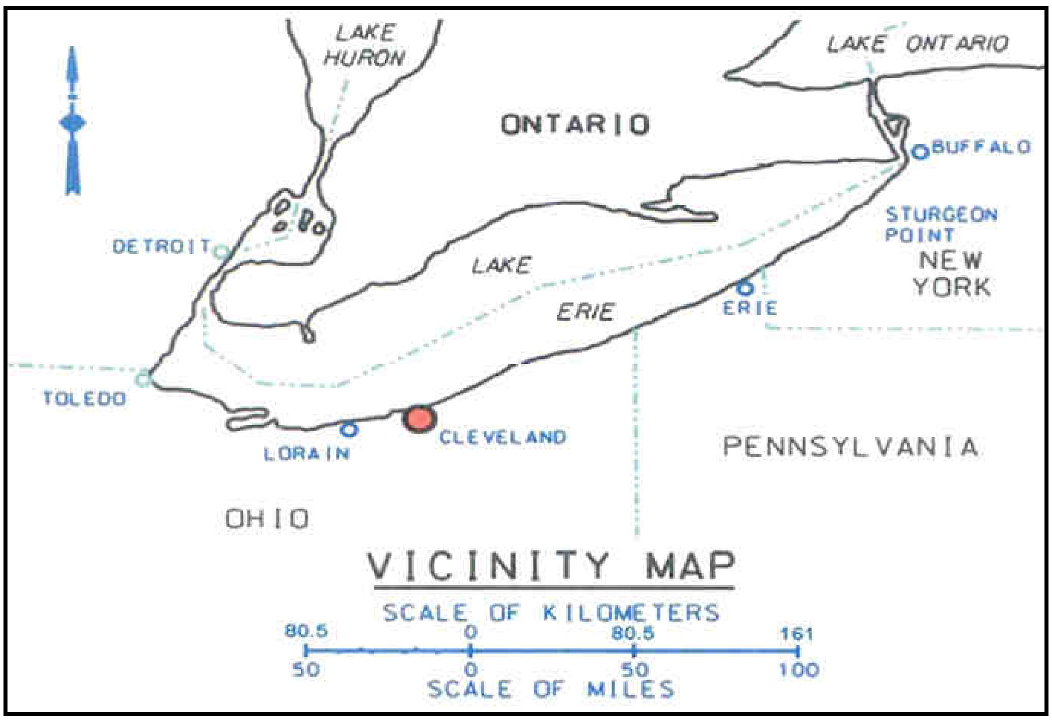
Recent extensive rehabilitation of the Burns Harbor North Breakwater in 2005 makes direct comparison of this 2006 Periodic Inspection to past monitoring impossible. This 2006 Periodic Inspection has provided data and documentation that can be used as a new baseline for future monitoring.

1.3 Project locations and brief histories

1.3.1 Cleveland Harbor, Cleveland, OH

Cleveland Harbor is located on the southern shore of Lake Erie, 96 miles east of Toledo, OH, and 176 miles west of Buffalo, NY (Figure 1). The Harbor is the 47th leading U.S. port with 13.6 million tons of material shipped or received in 2005, also ranking it 5th among the Great Lakes ports. Major commodities shipped or received include iron ore, limestone, sand and gravel, cement and concrete, salt, general cargo, and liquid bulk (USACE 2006).

Figure 1. Location of Cleveland Harbor, Cleveland, OH.



Construction of the harbor began in 1875 at the mouth of the Cuyahoga River with a stone-filled concrete pier. Early construction of the 6,084 feet (ft) West Breakwater consisted of stone-filled timber cribs and was completed in 1884. The design crest elevation of the West Breakwater was +12 ft low water datum (lwd) with a crest width of 32 ft. Since initial construction, a concrete cap, riprap, and a lakeside stone superstructure have been added to the West Breakwater. Early construction of the 20,970 ft East Breakwater began in 1887 and was completed in 1915. The westerly 3000 ft was constructed of stone-filled timber cribs with a concrete cap. A stone superstructure was added lakeside between 1917 and 1926

(Figure 2). The remaining easterly 17,970 ft was constructed using dumped core stone with large, individually placed armor stone at a design elevation of +10.3 ft lwd and a crest width of 10.0 ft (Figure 3). More details of early construction can be found in Bottin (1988).

Figure 2. Cross section of western 3,000 ft section of Cleveland Harbor East Breakwater as originally constructed.

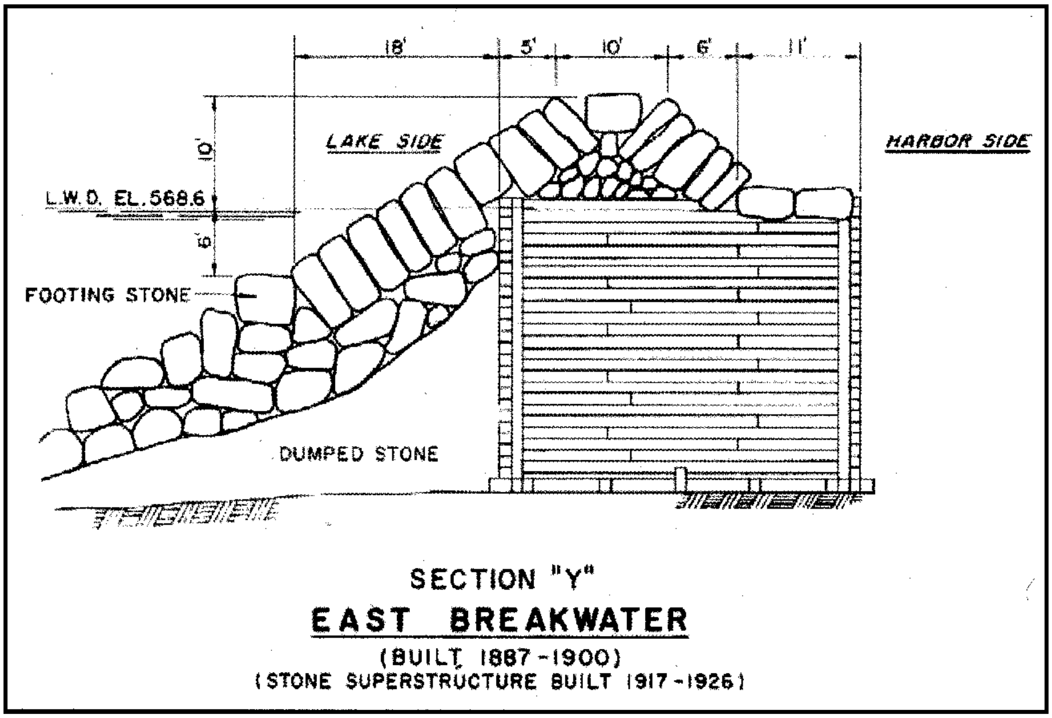
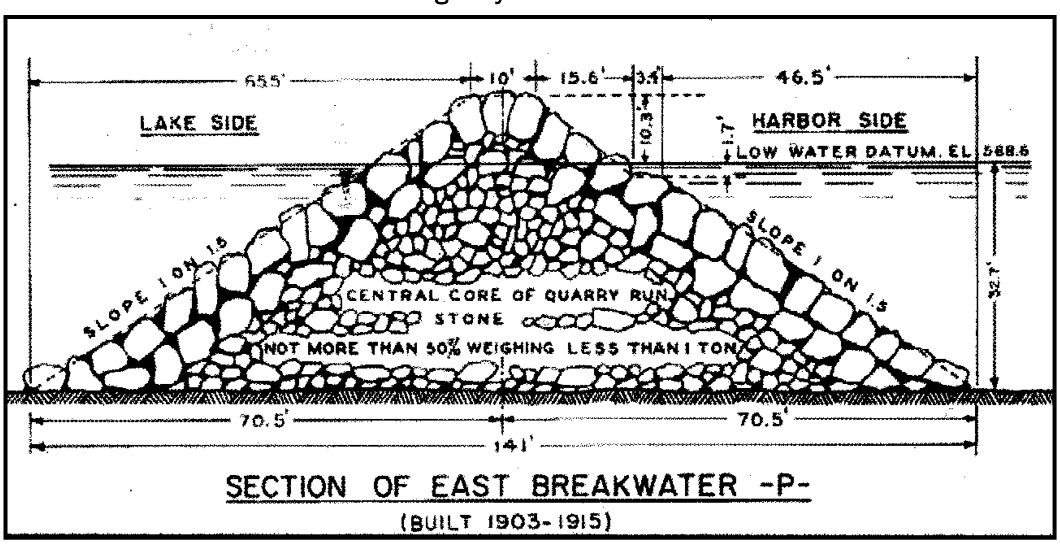


Figure 3. Cross section of eastern 17,970 ft section of Cleveland Harbor East Breakwater as originally constructed.



At that time, lwd on the Great Lakes (el 568.60 ft) was referenced to International Great Lakes Datum 1955 (IGLD55), which was mean water line (mwl) at Father Point, Rimouski, Quebec, Canada, at the mouth of the St. Lawrence Seaway. In 1985, lwd on the Great Lakes was redefined to el 569.20, and became IGLD85. The lwd on the Great Lakes also was the National Geodetic Vertical Datum of 1929 (NGVD29) at el 569.43 ft. Thus, NGVD29 was 0.23 ft higher than IGLD85.

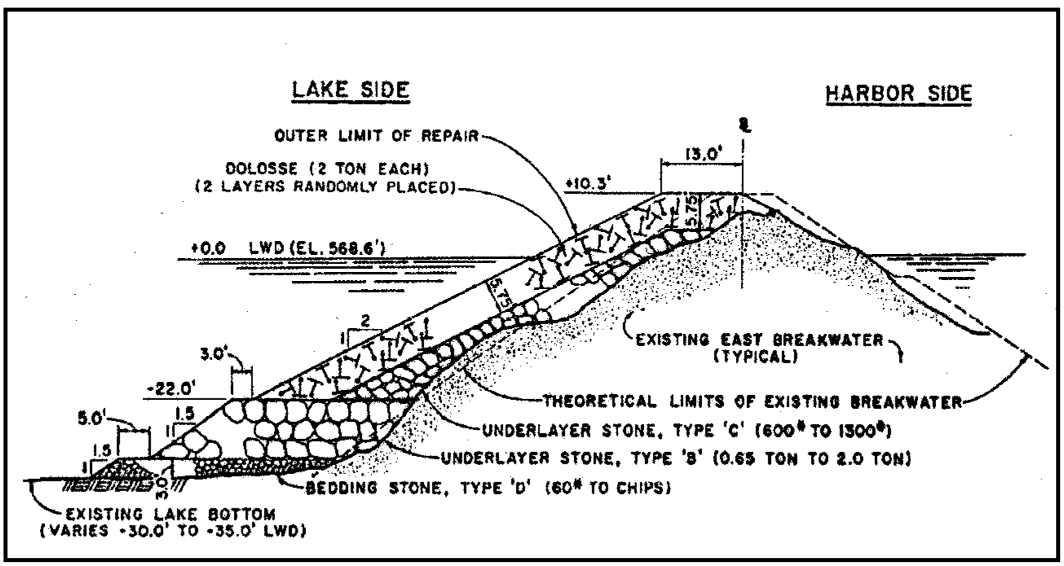
In 1971, the U.S. National Oceanic and Atmospheric Administration (NOAA), National Geodetic Survey (NGS), initiated a general adjustment of NGVD29. When completed in 1988, this adjustment became NAVD88. This minimum-constraint adjustment of Canadian-Mexican-U.S. leveling observations was performed holding fixed the height of the primary tidal benchmark referenced to IGLD85 local mean sea level height value at Father Point, Canada. This constraint satisfied the requirement of shifting the datum vertically to minimize impact of NAVD88 on U.S. Geological Survey mapping products and also provided the datum point desired by the IGLD Coordinating Committee. IGLD85 and NAVD88 are now one and the same, according to NGS (Zilkoski et al. 1992; Zilkoski 1993).

Presently, the East and West Breakwaters provide Cleveland Harbor with over 30,000 ft of navigation sheltering (Figure 4). There are two harbor entrances from Lake Erie. The westerly entrance is directly lakeward of the mouth of the Cuyahoga River. East and west rubble-mound arrowhead breakwaters were added to protect this entrance. They are each 1,250 ft long with a crest elevation of +8 ft lwd and a crest width of 10 ft. The easterly entrance is between the shoreline and the East Breakwater at the east end of the harbor. A U.S. Coast Guard lighthouse is mounted to a 21 by 21 ft square concrete base on the center of the East Breakwater head.

The East Breakwater has had an extensive repair and rehabilitation history. Storm damage caused armor stone displacement and subsequent unraveling of the breakwater slope in many areas. Frequent repairs were made using original construction methods until a major rehabilitation in 1979–1980. This construction involved the placement of 2-ton dolosse on the lakeward slope and damaged crest of the easterly 4,400 ft of the East Breakwater. Dolosse were placed at a 1V:2H slope on the breakwater trunk and a 1V:2.5H slope on the breakwater head to provide armoring (Figure 5).

Figure 4. Cleveland Harbor, Cleveland, OH, south shore of Lake Erie, looking east.

Figure 5. Cross section of major dolosse rehabilitation area of eastern 4,400 ft section of Cleveland Harbor East Breakwater following 1980 rehabilitation.

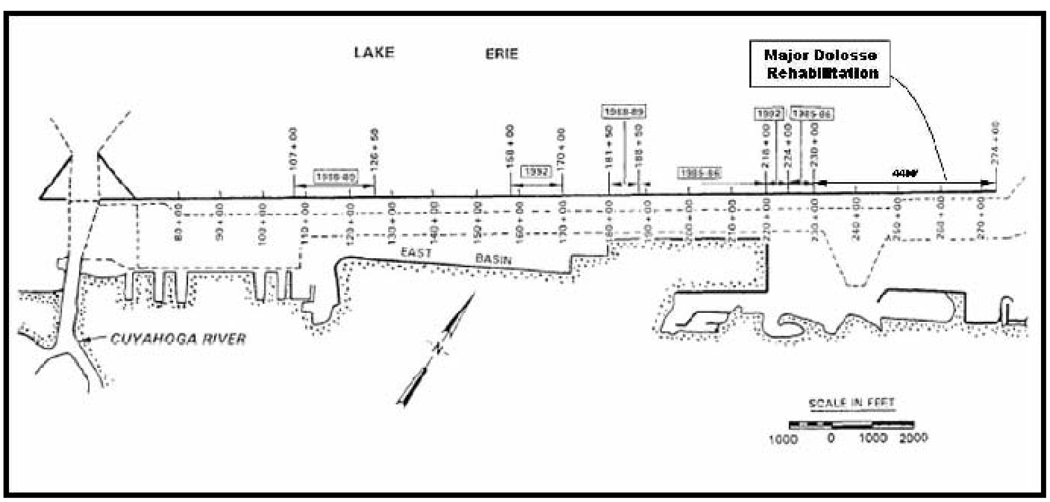


The winter of 1986–1987 resulted in higher-than-normal lake levels and produced several storms. In the spring of 1987, it was discovered that most of the 2-ton dolosse were missing from the head of the East Breakwater. These were replaced with 4-ton dolosse, and some additional armor units were placed in depressed areas along the trunk. Earlier laboratory tests and breakwater inspections supported the concept that the 2-ton dolosse were under designed for conditions at Cleveland Harbor East Breakwater

(Markle and Dubose 1985). An aerial photograph of the breakwater head (Figure 6) shows the size difference in the 2-ton and 4-ton dolosse. Other recent repairs to the East Breakwater took place in 1986, 1989, 1991, and 2001 on various sections of the westerly 16,570 ft. No dolosse were used in these areas. The harbor layout and repair/rehabilitation areas can be seen in Figure 7.

Figure 6. Aerial photograph of Cleveland Harbor East Breakwater head. Note the 4-ton dolosse used in 1987 repairs.

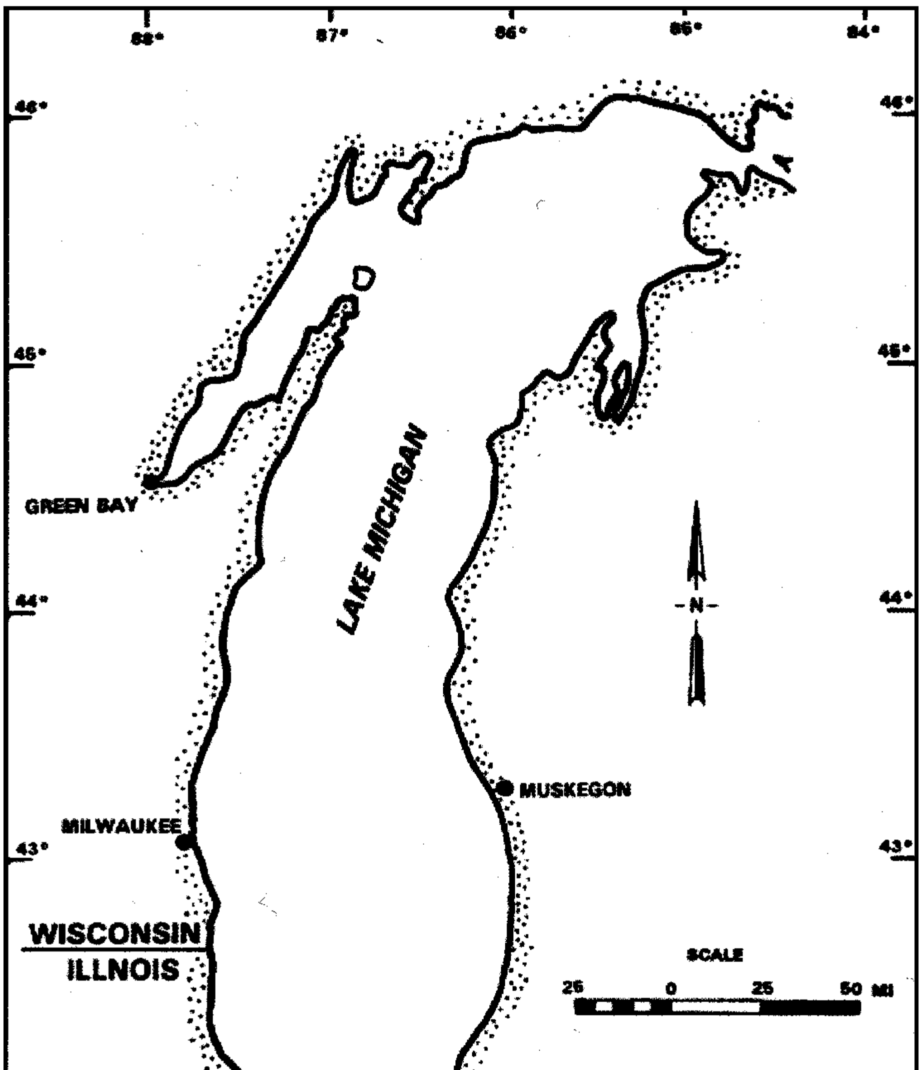
Figure 7. Cleveland Harbor East Breakwater layout with stone (1985–1992) and dolos (1986) rehabilitation areas.



1.3.2 Burns Harbor, Portage, IN

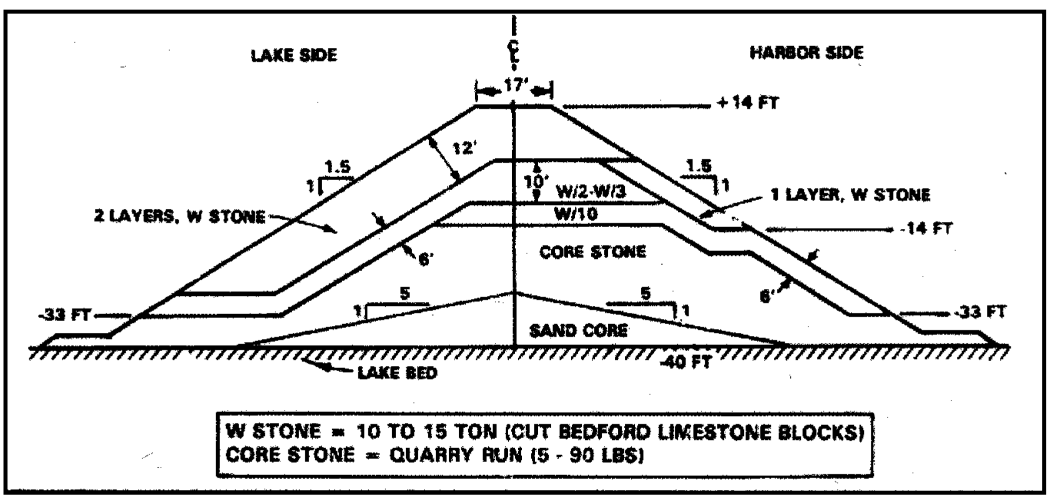
Burns Harbor is located approximately 30 miles by land and 18 nautical miles southeast of Chicago, IL, on the southern shoreline of Lake Michigan (Figure 8). It is the 56th leading port in the United States. Latitude and longitude coordinates for the harbor are 41⁰38’56” N, 87 ⁰08’45” W. An increase in industrial facilities in the area, namely steel corporations, and the opening of the St. Lawrence Seaway in 1959 increased the demand for navigational shipping and the need for a new deepwater port.

Figure 8. Project location for Burns Harbor, Portage, IN.



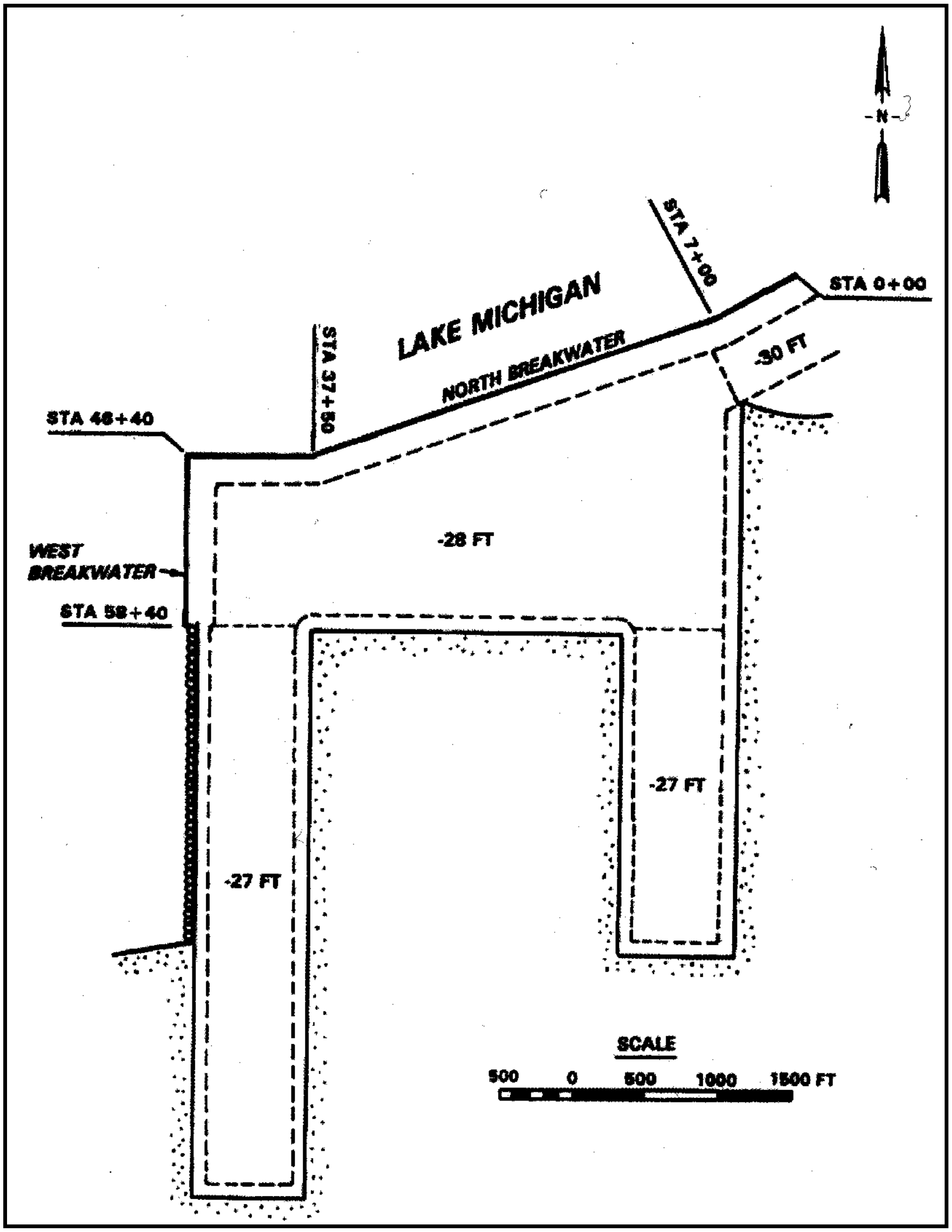
The state of Indiana created the Indiana Port Commission in 1960, and a USACE report recommended building a port at the present site (McGavock et al. 1969). Congress authorized the construction of the harbor by the River and Harbor Act of 27 October 1965. Design for the harbor layout was developed by the University of Florida (UF) (1964) for the Indiana Port Commission using a three-dimensional (3D) hydraulic physical model study to investigate wave and current phenomena associated with the proposed harbor (UF 1964). Detailed 1V:35H scaled two-dimensional (2D) physical model studies at ERDC (Waterways Experiment Station) were used to determine the final cross-section design for the breakwater in 1966 (Jackson 1967). This design was a multilayered rubble-mound structure with cut Indiana Bedford limestone armor. This armor was rectangular in shape, with each stone weighing between 10 to 15 tons on the trunk and 15 to 20 tons on the head. The armor was randomly placed in two layers which, at the time, was an unusual construction method. The design crest elevation was +14 ft lwd. The depth of the lakeside toe ranged from 31 to 41 ft. Side slopes on both lake and harbor sides were 1V:1.5H. Cross-section design for the original construction can be seen in Figure 9.

Figure 9. Cross section of original Burns Harbor North Breakwater.



Burns Harbor has 5,840 ft of breakwater structures including a 4,640 ft rubble-mound North Breakwater with an east-west alignment and a connecting 1,200 ft rubble-mound West Breakwater Arm with a north-south alignment toward the shoreline. A cellular sheet-pile extension connects the West Breakwater Arm to the shore. Lakeside toe depth ranges from -30 to -41 ft lwd. The authorized channel depth is -30 ft lwd at the entrance and -28 ft lwd in the Harbor. Original construction of Burns Harbor was completed in 1969. The harbor layout is shown in Figure 10.

Figure 10. Layout of Burns Harbor, Portage, IN.

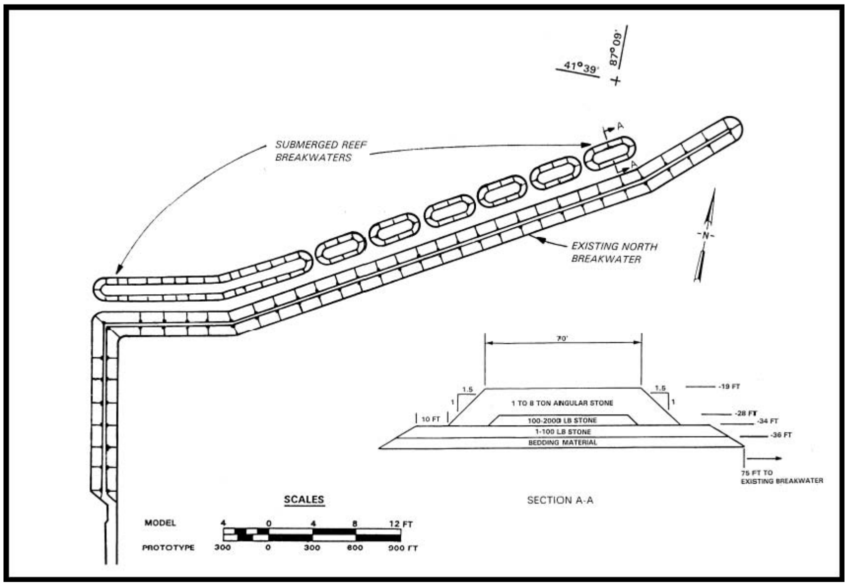


Burns Harbor North Breakwater has required extensive maintenance during its lifetime. In the first 19 years (yr) of existence, an average of 7,640 tons of stone per year was added to the North Breakwater (U.S. Army Engineer District, Chicago 1994). Between 1975 and 1989, 145,117 tons of maintenance stone were placed on the structure.

Meanwhile, damage due to excessive wave action was occurring in the Harbor interior and to vessels moored within the Harbor. Exceedingly

high cost and maintenance issues resulted in an extensive monitoring effort to evaluate the design process and to identify the causes of excessive wave energy in the harbor (McGehee et al. 1997). New physical model studies conducted at ERDC evaluated possible solutions (Carver and Wright 1995; Acuff and Bottin 1995). As a result of these efforts, a submerged reef breakwater system was constructed between 1995 and 1998, located 75 ft lakeward of the existing North Breakwater (Figure 11).

Figure 11. Layout of submerged reef breakwaters lakeward of existing North Breakwater, Burns Harbor, Portage, IN.



The purpose of this new reef-type structure was to reduce wave energy reaching the existing breakwater and, thereby, reduce breakwater damage and energy transmission into the Harbor. The reef system consists of seven separate segments. The westernmost reef was built 1,450 ft long, and the other six were each 275 ft long (head to head). The structure toes were 25 ft apart, and each had a width of 70 ft. They were each constructed at an elevation of -19 ft lwd. Figure 12 is an aerial photograph of Burns Harbor.

Figure 12. Burns Harbor, Portage, IN, south shore of Lake Michigan, looking north.

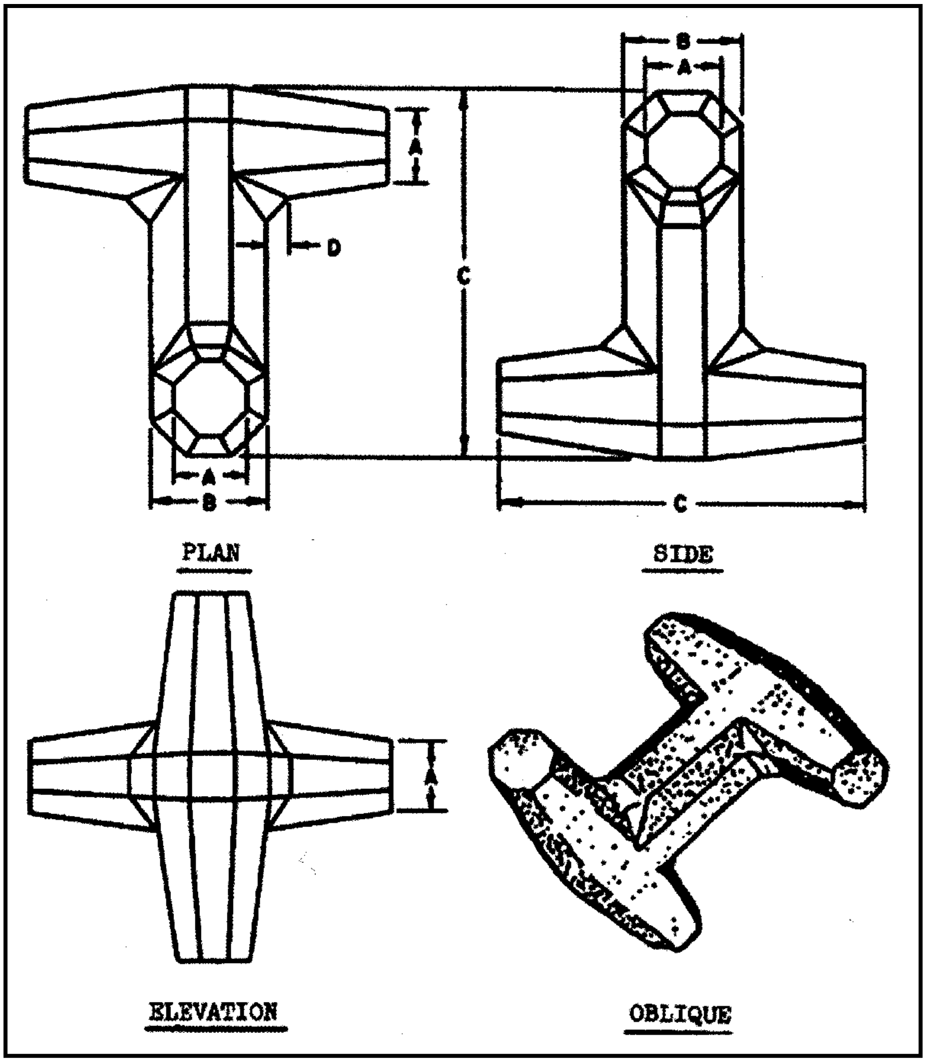
1.4 Dolos armor units and break types

In 1963, Eric Merrifield, a South African engineer for East London Harbor on the southern coast of Africa, witnessed a storm remove over half of the Harbor breakwater's solid armor units. Merrifield decided to design an armor unit that would allow for a porous breakwater, resulting in the dissipation of wave energy through the armor. They must be interlocking, affordable, and able to be installed in a random fashion. He designed the dolos (dolosse plural) to look similar to an "H" with one leg turned 90 degrees (Figure 13). Testing of Merrifield's design was conducted by the South African Counsel for Scientific and Industrial Research in 1965. Dolosse were shown to be more stable than other armor units of the time and were soon used on over 50 structures throughout the world (Pope et al. 1993).

Between the first placement of dolosse on the East London Harbor Breakwater, South Africa, in 1964 and the present, dolosse have been exposed to many different construction and storm conditions. Subsequently, weaknesses in the dolos design have been exposed. The

slender central sections and long legs produce very high stresses in the central sections of the units. This results in units that break into pieces having much less mass than the original unit. The broken units have little stability and may contribute to the breaking of adjacent units (Turk and Melby 1995).

Figure 13. Various views of a dolos armor unit.



The center section of the dolosse is referred to as the shank while the legs are called flukes. Dolos breaks were characterized according to Melby and Turk (1994) and recorded as one of the following during the walking inspections: (a) mid-shank, (b) shank-fluke (shank broken near one of the flukes), or (c) fluke-shank (fluke broken near the shank). Additional recorded details beyond those given by Melby and Turk included whether the breaks were straight or angled. This would indicate flexure or torsional shear failure. Damage was further specified as cracks, broken fluke tips,

and pieces. The latter was used to indicate severe breakage where only scattered remnants remained and the broken dolos could no longer be identified other than vicinity. Typically representative views of dolos break types at Cleveland Harbor East Breakwater are shown in Figures 14 through 17.

Figure 14. Example of a dolos angled midshank break.

Figure 15. Example of a dolos angled fluke-shank break.

Figure 16. Example of a dolos straight fluke-shank break.

Figure 17. Example of a dolos broken fluke tip.

2 Cleveland Harbor East Breakwater Prior Monitoring

2.1 Cleveland Harbor East Breakwater 1980–1985 initial monitoring

2.1.1 Dolos armor monitoring

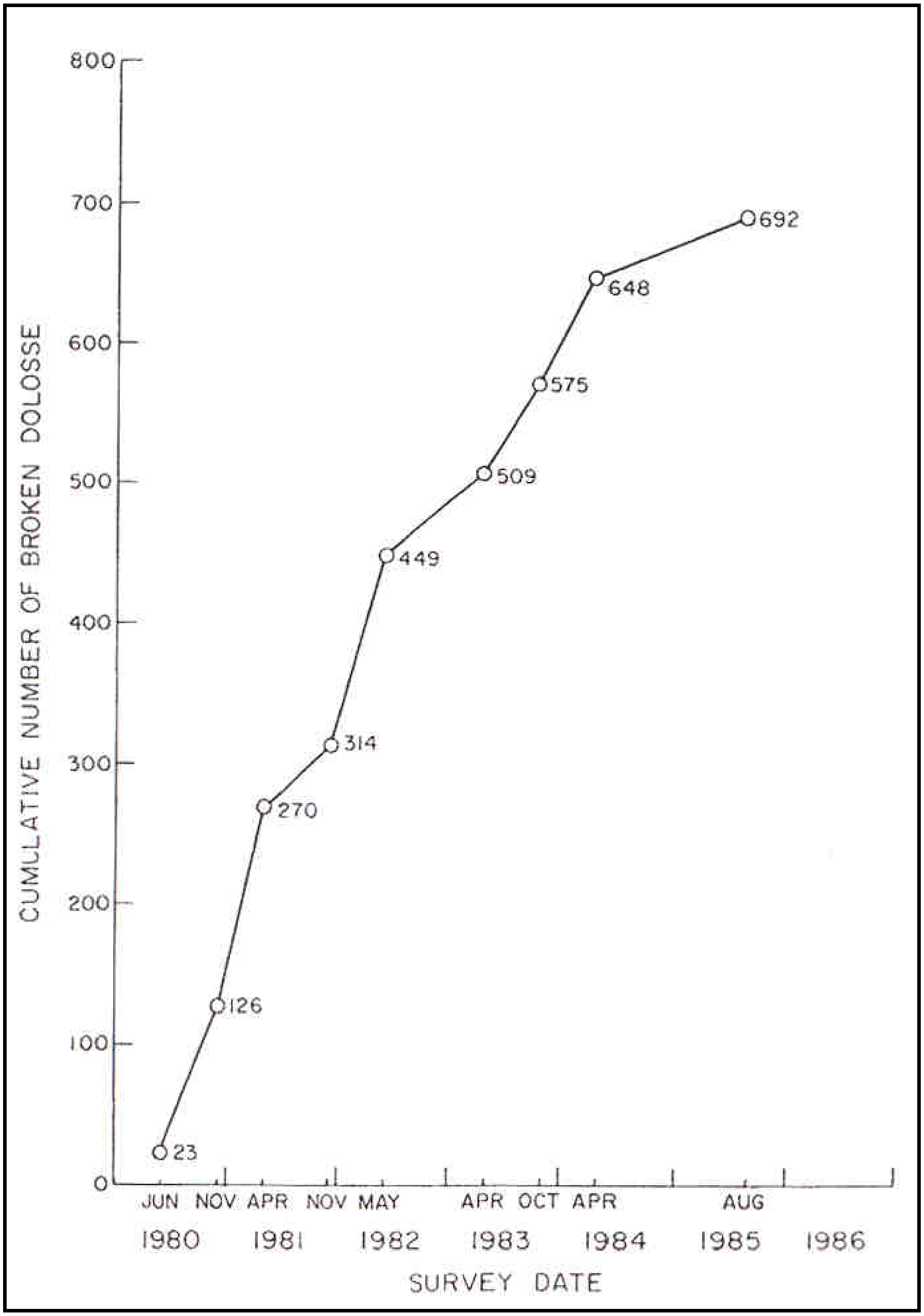
The first time dolosse were used on an offshore Great Lakes structure was the Cleveland Harbor East Breakwater major dolos rehabilitation project of 1979–1980. This dolos section of the breakwater, the easternmost 4,400 ft, was selected for monitoring by the MCCP (later MCNP) program in 1980. (The Periodic Inspections work unit did not exist at that time but was initiated in 1993.) The primary purpose of the dolos armor monitoring was to determine the stability of a dolos armored unit cover layer. Additional objectives were to (a) determine wave transmission by overtopping, (b) qualitatively evaluate run-up, and (c) document the effects of ice loading on the stability of dolos units.

Aerial photography, wave and water level data, survey data (to determine above waterline movement), time lapse photography, broken dolos unit inventory, and underwater surveys with both side-scan sonar and diver inspections were used in this comprehensive monitoring program. Method details of each can be found in Pope et al. (1993).

The monitoring program was originally scheduled to extend over a 3 yr time period, but a severe near-design lake storm on 6 April 1982 extended the program for an additional 2 yr, until September 1985. The storm resulted in the removal of 65 dolosse surrounding the head of the breakwater and noticeable armor movement and breakage along the trunk. Repairs to the breakwater head occurred in October 1982.

Above-water broken dolos inventories were conducted 10 times during the monitoring period. Records indicates that 692 broken units were documented. Of this number, approximately 60% of the breakage occurred following the first year of construction and a period surrounding a storm in April 1992 (Figure 18). Angled breaks outnumbered straight breaks, and most breaks were classified as fluke breaks. Of the shank breaks, the number of angled and straight breaks was approximately the same.

Figure 18. Cumulative number of broken dolos armor units located during 1980–1985 initial monitoring (comprehensive), Cleveland Harbor East Breakwater (after Pope et al. 1993).



It appeared there was no correlation between lake water levels and the number of armor unit breakage, though the water level may affect the location of damage on the breakwater. Increase in water level during

storm conditions may result in damage higher up on the structure and explain dolos breakage near the structure's crest. Also, lake water levels at the time of broken dolos surveys will affect the number of armor units visible to the survey team (Pope et al. 1993).

Concurrent with the monitoring effort, two-dimensional (2D) model studies were being conducted at CHL to determine wave stability of dolos and stone rehabilitation designs for the East Breakwater (Markle and Dubose 1985).

Conclusions and recommendations from the initial (1980–1985) dolos armor monitoring of Cleveland Harbor East Breakwater (Pope et al. 1993) included the following:

1. Although the 2-ton dolos armored layer had deteriorated over the years, the breakwater continued to provide the required level of shore protection. Maintenance of the dolos cover had been on an as-needed basis. Repairs, including repositioning and/or the installation of additional armor units, are required after major storms.
2. Wave reflection off the vertical concrete navigation light foundation at the breakwater head appeared to contribute to the loss of armor units in that area. Dolos armor layers were very porous. Wave energy was transmitted through the dolosse and reflected back upon them, apparently popping them out of place. Additional layers over reflective surfaces may be prudent for highly porous armor units.
3. As evidenced by significant movement and breakage, the 2-ton dolos appeared to be under-designed for the Cleveland Harbor East Breakwater. A 2-D model study also indicated that 4-ton armor units (as opposed to 2-ton) would decrease the probability of movement.
4. During the monitoring period, the 2-ton dolos cover continued to subside and lose elevation. Breakage of armor units also occurred throughout the monitoring period, but the rate of breakage appeared to decrease slightly toward the end of the monitoring period. Most breakage occurred along the waterline in the active wave zone. Little breakage was noted below the waterline during diving inspections.
5. Aerial photography of the dolos cover proved to be a useful tool during the monitoring program in spite of the fact that the photos were not completely rectified. Photos were used to evaluate qualitative changes in the armor cover. This photography served as the basis for planning maintenance and repair of damage zones during the monitoring period.

6. Wave gauges were not deployed at Cleveland Harbor during the winter months because of concern that they would be lost to ice. Unfortunately, most severe storms during the monitoring period occurred during the winter. The wave data collected, therefore, were not representative of the most severe storm conditions.
7. Side-scan sonar surveys proved to be a valuable means for obtaining qualitative documentation of the condition of the structure toe and the consistency of the cover layer slope. Combined with diving surveys, the underwater condition of the dolos cover was determined to have several flaws from original construction, including zones of no armor and areas where the toe appeared to be unstable.
8. Since dolos breakage can jeopardize the structure's integrity, dolosse should be designed for "no-rocking" criteria to minimize breakage resulting from movement. This was reported by Melby and Turk (1994) when reviewing past dolos project performance. Consideration also should be given to reinforcement of dolosse in the active wave zone for a deepwater structure, since breakage appeared to be concentrated in this area. Additionally, dolosse should be placed over a stone underlayer rather than against a flat surface to prevent movement caused by wave reflection.
9. The 2-D model study investigation, conducted subsequent to prototype construction, indicated that the dolos cover at Cleveland Harbor would be unstable for wave conditions in excess of 10.5 ft. When new breakwater cover concepts are being considered, a model investigation incorporated as part of the design would help in selecting the optimum cover unit. Proper design will minimize repair and rehabilitation costs during the life of these projects.
10. Aerial photography targets and dolosse identified for armor unit surveys at Cleveland ranged from 300 to 900 ft apart. More detail would have been useful in rectifying stereo-pairs. For future monitoring efforts, it was recommended that controls be established to place at least three targets in each photo frame.

2.1.2 Stone armor monitoring

Major stone rehabilitations, followed by extensive stone cracking in a relatively short time frame, led to an intensive quality assurance/quality control (QA/QC) effort (Marcus 1994). Three armor stone reaches, Reach 1 (sta. 197+65 to sta. 198+65), Reach 2 (sta. 107+50 to sta. 108+50), and Reach 3 (sta. 164+00 to sta. 164+55), each with uniquely different stone characteristics and placements, were chosen for monitoring in 1989, 1990, and 1992, respectively. (The locations of the three reaches can be found in

Figure 7.) The purpose of armor stone monitoring was to gain a better understanding of stone durability relating to the natural and man-made causes for early stone degradation. Details of methods and data can be found in Bottin et al. (1995).

Results of the initial (1989, 1990, and 1992) stone armor monitoring at Cleveland Harbor East Breakwater (Bottin et al. 1995) included the following:

1. Detailed geologic cracked stone investigations performed during breakwater walking inspections proved to be a successful method for observing minute crack formation and crack damage development otherwise missed by routine boat or aerial observation.
2. The sequential photographing of individual stone damage on an annual basis, with cracks and crack damage spray painted and recorded, provided viable, visual documentation of the stone cracking problem occurring on the breakwater.
3. Annual photographic sequences and photographic comparisons proved to be a highly successful tool in assisting with quantification of damage type over time.
4. Breakage of armor stone occurred along the entire profile of the structure; however, most severe breakage (where displacement of stone pieces occurred) took place along the waterline, in the active wave zone.
5. Early indications suggest that enhanced QC/QA stone inspections yield better end-quality products than the current standard Corps QC/QA inspections.
6. As evidenced by continued cracking and crack damage advancement, a severe problem existed on the above-water armor stone on the Cleveland Harbor East Breakwater. Further studies using the completed database may provide new insight on the future of stone durability in coastal structures.

2.2 Cleveland Harbor East Breakwater 1993 Periodic Inspections monitoring

In June 1993, monitoring of the Cleveland Harbor East Breakwater was conducted by the recently created (1993) Periodic Inspections work unit of the MCNP. The objectives were to re-examine the breakwater to determine changes that had occurred since the MCCP program ended in 1985 and to establish above-water armor unit baseline data upon which long-term stability could be defined through periodic inspections (Bottin et al. 1995).

The 1993 inspection included the easternmost 4,400 ft dolos section and three representative stone sections selected by CELRB. The stone sections included the previously studied Reaches 1, 2, and 3, with adjacent additions more than doubling the area that was studied in previous years. Reach 1 included a new 135 ft section (sta. 198+65 to sta. 200+00) in addition to the adjacent historical reach study area (sta. 197+65 to sta. 198+65) monitored from 1989–1992. Reach 2 involved monitoring an additional 100 ft section (sta. 108+50 to sta. 109+50) adjacent to the historical reach area (sta. 107+50 to sta. 108+50) monitored from 1990–1992. Reach 3 entailed monitoring 180 ft of the structure (sta. 163+60 to sta. 165+40) as opposed to 55 ft (sta. 164+00 to sta. 164+55) monitored in 1992.

Low-altitude aerial photography, target and ground surveys, photogrammetry, and walking broken-armor-unit surveys were used in this comprehensive monitoring program. Method details of each can be found in Bottin et al. (1995).

A ground survey and Global Positioning System (GPS) control surveying were used to establish monuments (Figure 19) on land and on the cap of the breakwater to serve as horizontal and vertical control points. Ground

Figure 19. Example of a survey monument on Cleveland Harbor East Breakwater.

surveys were referenced to known National Geodetic Survey Stations 1702 and G321. GPS coordinates were assigned to the existing monuments 27, 808, 809, 810, and 813, and to newly established monuments RBD1 through RBD15, located at approximately 500 ft intervals.

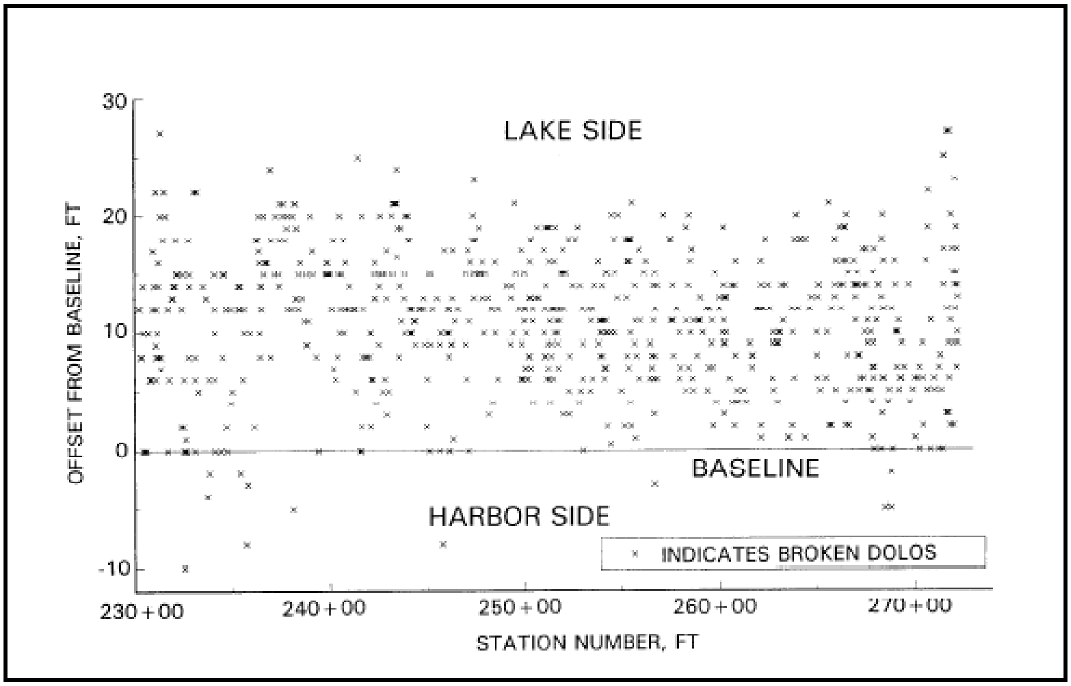
Horizontal Planes are based on the Ohio State Plane Coordinated System, and all elevations are referenced to North American Vertical Datum 1988 (NAVD88). Monument positions for the June 1993 are listed in Table 1.

Table 1. Monument positions for 1993 survey of Cleveland Harbor East Breakwater.

Monument	Easting	Northing	Elevation, NGVD88 (ft)	Station, (ft)	Offset from Center Line, (ft)
1702	2190621.17	672734.83	583.5	118+10.56	3303.4 1S
G321	2205531.66	683682.4	583.33	303+03.48	6267.82S
27	2187673.58	674633.95	577.84	106+34.82	0
808	2196747.34	681624.86	577.38	220+89.34	0.49S
809	2199140.85	683469.78	578.75	251+11.36	0.04N
810	2200824.79	684767.24	583.53	272+37.16	0
813	2188107.18	674968.53	579.45	111+82.50	0.38N
RBD1	2200613.46	684604.44	579.04	269+70.40	0.02N
RBD2	2200222.37	684303.05	578.03	264+76.65	0.01S
RBD3	2199845.75	684012.92	578.52	260+01.24	0.04N
RBD4	2199449.74	683707.77	579.09	255+01.30	0.03.N
RBD5	2199053.71	683402.56	578.63	250+01.30	0.02S
RBD6	2198657.31	683097.03	577.71	245+00.82	0.09S
RBD7	2198253.45	682785.74	577.76	239+90.91	0.18S
RBD8	2197863.2	682484.95	577.27	234+98.20	0.25S
RBD9	2197468.63	682180.77	578.26	229+99.99	0.38S
RBD10	2195073.31	680342.83	578.56	199+80.80	5.73S
RBD11	2194801.37	680130.05	578.9	196+35.52	3.16S
RBD12	2192512.87	678361.47	579.95	167+43.27	0.99S
RBD13	2192165.53	678100.29	576.46	163+08.72	4.12N
RBD14	2187929.05	674831.07	578.67	109+57.50	0.22N
RBD15	2187710.78	674662.65	578.55	106+81.81	0.03N
RBD16	2194043.51	678211.45	582.06	178+64.17	1054.07S

The June 1993 broken armor unit monitoring of the dolos section indicated 782 broken/cracked dolos above the water line. Forty-eight of these had multiple breaks. Only 7 of the 782 were 4-ton units. A distribution of damaged dolos relative to station number can be seen in Figure 20.

Figure 20. Distribution of broken dolos armor units along Cleveland Harbor East Breakwater relative to station number, June 1993 monitoring (after Bottin et al. 1995).



The broken armor unit monitoring for the stone armor was subdivided into the three reach areas and was summarized by Bottin et al. (1995) as follows:

- **<u>Reach 1 (sta. 197+65 to sta. 200+00):</u>** The armor consists of 9- to 20-ton Dolomite Limestone on 1V:1.5H side slopes. One hundred and forty stones were fully documented. Of the previously inspected 59 stones, 10 stones showed no new damage while increased crack damage was noted for the other 49. New cracking seemed to occur randomly. Sixty-one of the 89 newly monitored stones revealed significant cracking (68.5 percent). Seventy-four percent (110 of 148) of above-water stones for the entire 235-ft study reach contained significant damage. The stone damage was largely attributed to blast fractures, and to the geologic composition the quarry used.
- **<u>Reach 2 (sta. 107+50 to sta. 109+50):</u>** For Reach 2, the same stone sizes and slopes were used as on Reach 1. The difference was an

intensive QA/QC effort conducted prior to construction as a result of the high percentage of damage to Reach 1. One hundred and twenty-nine 9- to 20-ton Dolomite Limestone armor stones were documented for the entire 200- ft section. Only 24 of the 129 (19 percent) stones were considered unsatisfactory because of significant cracking compared to an 18 percent unsatisfactory rate recorded on the original Reach 2 (sta. 107+50 to sta. 108+50) between 1990 and 1992. This suggests that the damage had leveled off, and that the QA/QC effort had been successful.

- **Reach 3 (sta. 163+60 to sta. 165+40):** In 1992, sta. 158+00 to sta. 170+00 and sta. 218+00 to sta. 224+00 were rehabilitated. This included the installation of 4.3- to 9.6-ton Dolomite Limestone from a different quarry than used for Reaches 1 and 2. These were placed using a 1V:2H slope. The smaller stone and flatter slope were used with the intention of improving stone durability. Standard acceptance procedures, not the enhanced QA/QC, were used in the selection of stone. The initial Reach 3 monitored in 1992 was only 55 ft long from sta. 164+00 to sta. 164+55. The 1993 monitoring effort increased the area to 180-ft section. Here, 152 above-water stones were monitored. Of the 152 stones documented, 35 (23 percent) had significant cracks less than two years after placement. Twenty-eight stones had damage attributed to blasting fractures.

2.3 Cleveland Harbor East Breakwater 1997 Periodic Inspections walking inspection

In 1996, an HQUSACE program review requested that structures studied during past MCNP efforts be revisited to determine how they are performing in their respective environments. The monitoring effort was designed to be expedient and low cost. There would be no instrumentation or detailed data but rather walking inspections and/or boat surveys focusing on the generalities of structures. Armor positions were compared to previous aerial photographs when applicable. Obvious voids and settlements were noted, and structure photographs were recorded. Subsequent references to *walking surveys* or *walking inspections* refer to this type of monitoring based on the 1996 HQUSACE program review.

The Cleveland Harbor East Breakwater was selected as one of 14 sites to be visited for this effort and was inspected in October 1997.

Results of the walking inspection and suggestions are summarized by Bottin and Tolliver (1999) as follows:

> Inspection of the Cleveland Harbor East Breakwater, OH, indicated that the structure had changed little since the previous survey of 1993. Comparison of armor unit positions revealed that most were in the same locations. Even fragments of broken units were in the same positions. Apparent armor unit movement was observed at only one location on the breakwater. Numerous broken units were observed but verified as being broken during the 1993 survey. The structure is in fair-to-good condition, and appears to be functioning well. It should be inspected periodically, and particularly after storm events.

2.4 Cleveland Harbor East Breakwater 2004 Periodic Inspections walking inspection

In June 2004, a walking inspection of the Cleveland Harbor East Breakwater was conducted. Results and recommendations are summarized by Bottin et al. (2004) as follows:

> Inspection of the Cleveland Harbor East Breakwater, OH, indicated overall that the structure armor unit (dolosse) positions had not changed significantly since the previous inspection. Several voids [Figure 21] and low areas were noted, however, on the sea side of the breakwater slope as well as an area of subsidence on the crest. Excessive vegetation also was noted on some areas of the structure, and numerous broken armor units were observed, most of which had been noted as broken during the previous surveys. The structure was in fair-to-good condition, and appeared to be functioning well.
>
> Consideration should be given to placing additional armor units in the voids and low areas during scheduled maintenance, and to removing the overgrown vegetation. The breakwater should be inspected periodically, particularly after storm events. It has been 11 years since the structure was formally monitored under the MCNP program. A photogrammetric survey should again be conducted to quantify armor unit movement, and analyze the armor cover layer over this time frame.

Figure 21. Example of void on lake side of Cleveland Harbor East Breakwater between sta. 230+40 and sta. 230+70, 2004 walking inspection.

3 Burns Harbor North Breakwater Prior Monitoring

3.1 Burns Harbor North Breakwater 1985–1992 initial monitoring (comprehensive)

Burns Waterway Harbor North Breakwater was selected for an intense monitoring effort through the MCCP program in 1984. The monitoring was conducted during the period 1985–1992. The primary purposes were to determine the cause of loss of crest elevation of the breakwater and to evaluate excessive wave conditions in the harbor. The approach of the monitoring effort was to (a) evaluate the design process, (b) identify the causes of complaints of excessive wave energy by harbor users, and (c) determine the causes for frequent necessary maintenance requirements. A comprehensive historical review and characterizations of the breakwater foundation, breakwater stability, and waves on both the inside and outside of the harbor were conducted as part of the monitoring effort.

Some of the methods employed included site inspections, dive inspections, side-scan sonar surveys, geotechnical data collection, and wave and water level data collection. Details of the initial monitoring conducted during 1985–1992 can be found in McGehee et al. (1997). Results of this initial monitoring are summarized in Hales and Richie (2004) as follows:

> Operational problems frequently occurred in the harbor. Prototype wave gauging at the site revealed an approximate 30 percent transmission coefficient for the breakwater. This was attributed to the structure's high porosity. Therefore, when incident waves exceed 10 ft (an annual occurrence), the 3-ft operational criteria in the harbor were exceeded. The harbor was functioning, though not to the satisfaction of the users.
>
> Analysis of design procedures used for Burns Harbor revealed that the design wave and water level were severely underestimated prior to original breakwater construction. Additionally, a 3-D model investigation under-predicted wave heights throughout the harbor, because it used an impermeable breakwater (as opposed to a porous structure). A 2-D model also over-predicted armor stone stability

and under-predicted transmission. These model investigations were performed in the early 1960s.

The structure was determined to be under-designed, principally due to underestimation of the wave climate in Lake Michigan. An improved hindcast, supplemented with wave data, produced an updated extremal analysis. The original 13-ft design wave was determined to be a 2-year event (McGehee et al. 1997).

The breakwater had experienced considerable damage over its life, but no single storm or specific event has caused loss of a section below the waterline. The loss of armor stones on the crest was assumed to be caused by high wave action. The structure had experienced waves larger than its design condition on numerous occasions. Harbor-side armor damage was assumed to be due primarily to overtopping and/or transmitted waves.

The crest elevation of the breakwater was 1.0 ft below its design elevation, on the average. There was evidence that the foundation may not have been constructed appropriately, thus causing greater settlement of the breakwater than anticipated. Excavation of clay from beneath the breakwater was placed lakeward of the structure. Clay deposition piles noted during the geotechnical portion of the monitoring make it believable that some of the clay washed back into the trench prior to construction. Additionally, the presence of large sand piles on the lake bed indicated that a significant portion of the sand backfill material for the trench may have been placed lakeward of the proposed structure location, and not actually placed in the trench.

The structure may have experienced greater than anticipated settlement, though the difficulty of evaluating historical survey data and variation in settlement along the structure hampers attempts to estimate the actual settlement. Both the original geotechnical design and a subsequent reanalysis predicted average settlement of about 1 ft. However, statistical analysis of the survey data suggests the structure has settled an average of about 2.0 ft. This settlement represents “loss” of armor stone on the order of 100 kilotons, roughly equivalent to the amount of repair stone placed on the structure over its life.

Alternatives for the reduction of maintenance of the breakwater were to (1) add larger stone and/or increase the angle of the slopes, (2) add a concrete cap to the structure to improve stability of the crest, or (3) place a protective structure (reef-type structure well below the water level) in front of the existing breakwater. An economic analysis was conducted to determine which alternative(s) would result in reduced overall costs. (Alternative 3 was selected subsequent to this 1985 thru 1992 monitoring of the site, and was constructed in the prototype).

The cut stone armor used in the breakwater exhibited a wider variance in stability than associated with typical rubble mounds. The result is a highly variable pattern of damage on the structure. The stability of cut stone armor is more sensitive to placement technique than other types of armor. Weathering of the armor resulted in some breakage, but not a significant amount.

A 3-D model study used to plan the harbor resulted in an ineffective entrance design. That study did not accurately predict wave conditions in the harbor because it assumed all wave energy would enter the harbor through the entrance (impermeable breakwater; no overtopping), and also it underestimated the design wave.

A 2-D model study used to design the breakwater cross-section underestimated wave transmission, possibly caused by settlement of the structure and subsequent repairs that resulted in a more porous structure. The 2-D model study appeared to predict the stability, but did not accurately predict the harborside damage that was approximately equal to the lakeside damage over the life of the structure.

The functional requirements of the project changed since design because of an increase in barge traffic in the harbor. Most of the user complaints regarding operations could be traced to one facility, the grain dock on the north wharf which was constructed with a vertical sheet-pile face. Measurements verified that reflection caused wave conditions in front of the dock to be twice the height of waves in the open area of the harbor. This facility with a vertical sheet-pile face was not anticipated in the design phase.

3.2 Burns Harbor North Breakwater 1994–1995 Periodic Inspections monitoring (base conditions)

During the period November 1994–July 1995, monitoring of the Burns Harbor North Breakwater was conducted as part of the MCCP (presently MCNP) program under the Periodic Inspections work unit that had been initiated in 1993. Purposes of the monitoring by Bottin and Matthews (1996) included the following:

- develop methods using limited land-based surveying, aerial photography, and photogrammetric analyses to assess the long-term stability response of the stone armor layer on the Burns Harbor North Breakwater
- conduct land surveys, broken armor stone inspections, aerial photography, and photogrammetric analyses to
  - test and improve developed methodologies, and accurately define armor unit movement above the waterline
  - establish base condition for the North Breakwater's armor units so that this structure could be remonitored in the future under the Periodic Inspections work unit.

Accomplishments included (a) establishing targets and photo control points for aerial photography and photogrammetry, (b) conducting ground surveys using existing monuments (similar to Cleveland Harbor East Breakwater monuments, Figure 19) to serve as horizontal and vertical reference points, and (c) performing a detailed walking survey of the broken stone armor units.

Details of the July 1995 Periodic Inspections monitoring of the 4,640 ft structure were summarized by Bottin and Matthews (1996) as follows:

> Each broken armor stone was identified and photographed, and its location relative to breakwater station and distance from a baseline was recorded. The baseline was approximately the centerline of the structure. Armor stones with hairline cracks were not counted; only those that were cracked all the way through were included. The lake level was +2.0 ft lwd.
>
> The survey revealed a total of 165 broken or cracked armor stones above the waterline. Of these, 26 were located along the breakwater

> crest, 95 on the lakeside slope, and 44 on the harbor side slope. No broken armor stones were observed around the head of the structure. Broken stones occurred along the entire North Breakwater trunk but, in general, high concentrations were found along the eastern-most portion of the structure. About 50 percent of the broken units (82 units) were located on the eastern one-third (1,500 ft) of the structure. The majority of the broken armor stones along the structure (57 percent) were located on the lake-ward face of the structure in the active wave zone. About 16 percent of the broken armor units were on the crest of the breakwater, and 27 percent were on the harbor side of the structure. The detailed data obtained during this walking survey will allow for an accurate indication of any new breaks that may occur prior to the next structure re-survey.

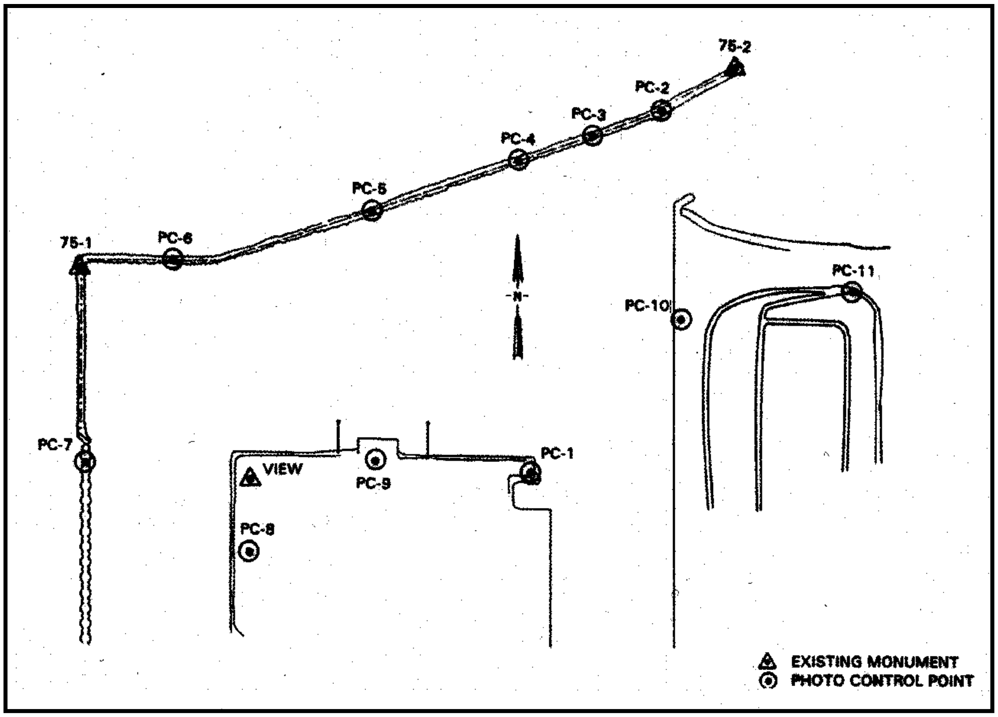
3.3 Burns Harbor North Breakwater 1999 Periodic Inspections walking inspection

In August 1999, a Periodic Inspection was conducted of the North Breakwater (Bottin and Tibbetts 2000) to compare with data obtained during the previous Periodic Inspection of 1994–1995 (Bottin and Matthews 1996). Targets and control points are shown in Figure 22. Prior to this monitoring, construction of the submerged, segmented reef breakwater was completed on the lake side of the North Breakwater. The 1999 effort established new baseline data to determine future effectiveness of the reef system relative to damage of the existing North Breakwater.

Results of the August 1999 monitoring of Burns Harbor North Breakwater by Bottin and Tibbetts (2000) are summarized by Hales and Richie (2004) as follows:

> Results indicated continued loss of structure elevation. Approximately 46 percent of the total length of the breakwater was below the design crest elevation of +14 ft versus 24 percent in 1995. Also, about 11 percent of the structure was below an elevation of +12 ft in 1999 versus 4.6 percent in 1995. Both surveys indicated crest width along the breakwater narrower than design and slopes on the harbor side of the structure steeper than design.

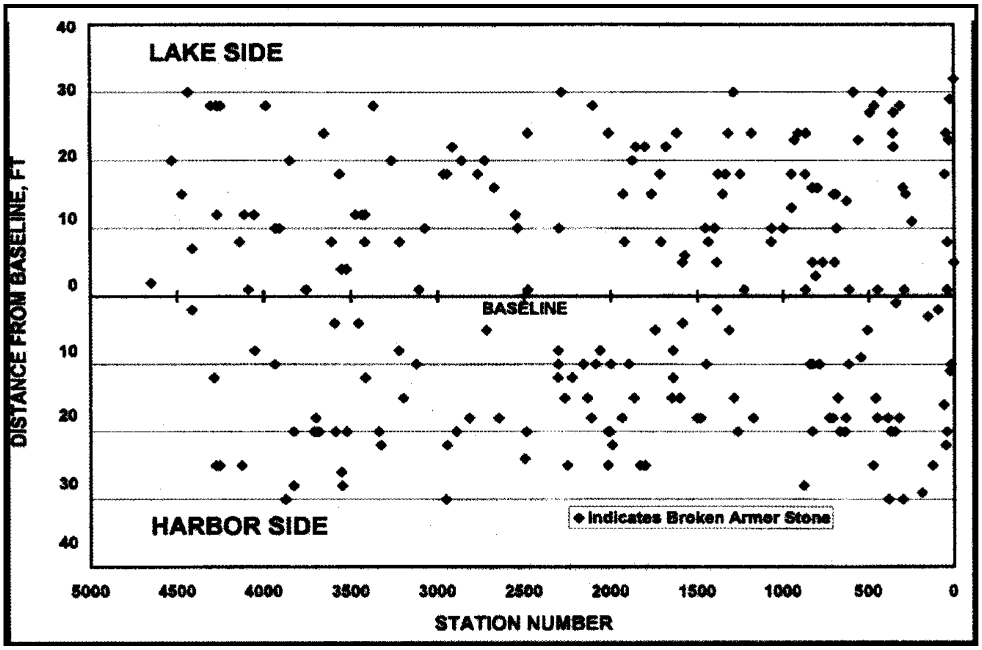
Figure 22. Control points for Burns Harbor North Breakwater August 1999 walking inspection.



A total of 225 broken armor units were documented during the 1999 survey [Figure 23] versus 165 during the previous survey. Data indicated the majority of additional stone breakage occurred on the harbor side of the structure as opposed to the lakeside. As in the previous survey, higher concentrations of broken stone were noted on the eastern one-third of the breakwater during the current monitoring effort.

To reduce wave heights at the breakwater and minimize further damage, a submerged reef breakwater had been constructed lakeward of the original structure during the construction seasons between June 1995 and August 1998. The photogrammetry conducted in 1999 not only quantified changes since 1995 but established new base conditions for the structure upon which the performance of the reef breakwater can be evaluated in future years.

Figure 23. Distribution of broken armor stones on Burns Harbor North Breakwater, August 1999 walking inspection (after Bottin and Tibbetts 2000).



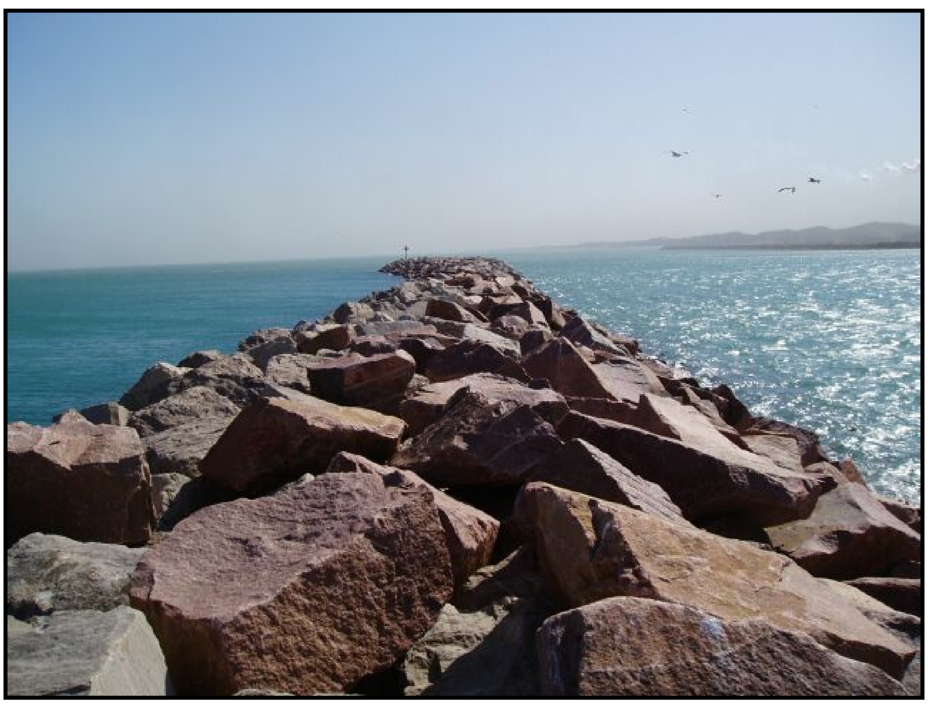
3.4 Burns Harbor North Breakwater 2004 Periodic Inspections walking inspection

In April 2004, a walking inspection of the Burns Harbor North Breakwater was conducted. Numerous repairs to the structure had been completed since the 1999 inspection to flatten slopes and raise the crest elevation to design levels, with more work scheduled for 2004 and 2005. Comparison views of the breakwater are shown in Figures 24 and 25. Results and suggestions are summarized by Bottin et al. (2004) as follows:

> Inspection of the Burns Harbor North Breakwater in 2004 revealed that the structure's cross section was significantly improved compared to the previous inspection in 1999. Several steep areas were noted during the inspection on the seaside and harbor-sides of the breakwater, as well as an area of crest subsidence. However, most deficiencies were in reaches that were not recently repaired. Overall, the breakwater was in good condition, and recently repaired portions were in excellent condition. The structure should be inspected periodically, particularly after major storm events. After repairs are completed in 2005, consideration should be given to monitoring the structure through photogrammetry to establish new base conditions upon which to evaluate the performance of the rehabilitated breakwater.

Figure 24. Burns Harbor North Breakwater, August 1999 walking inspection, looking east.

Figure 25. Burns Harbor North Breakwater, April 2004 walking inspection after repairs, looking east.



4 2006 Periodic Inspections Monitoring Plan and Walking Inspections

The objective of the 2006 Periodic Inspections monitoring was to revisit previously monitored sites to determine and define changes in those breakwaters. To accomplish this, sites were prioritized by HQUSACE and ERDC, with Cleveland Harbor East Breakwater and Burns Harbor North Breakwater being selected as two sites with the most critical need for re-evaluation monitoring.

Reasons for the selections included the following:

1. Extensive rehabilitations and repairs to the Burns Harbor North Breakwater dictated a need to establish new baseline data to better understand the effectiveness of the submerged reef system.
2. A detailed monitoring of the Cleveland Harbor East Breakwater had not been conducted in 13 yr, longer than any previously monitored location within the Periodic Inspections work unit.
3. The close proximity of the two sites allowed for work to be conducted concurrently, contributing to significant cost savings.
4. JALBTCX was scheduled to conduct lidar topographic survey flights on both Cleveland Harbor and Burns Harbor in the summer of 2006.

A new approach, when compared to past monitoring efforts, was implemented by incorporating some of the older proven methods with newer ideas. For these surveys, aerial photography and photogrammetry were not used. Funding limitations and a significant increase in costs of contracting aerial photography and photogrammetry services mandated the need for adaptation of more cost-effective surveying technology.

The 2006 monitoring plan consisted of limited ground-truth surveys, broken armor unit surveys, and utilization of lidar flights. In addition to monitoring both Cleveland Harbor and Burns Harbor breakwaters, a significant strategic investment was put into the development of a Geographic Information System (GIS) specific to Periodic Inspections work unit sites.

4.1 Ground-truth surveys

Ground-truth surveys are used to establish base conditions for a breakwater's armor units and serve as controls for future comparisons. Typically, monuments as described in Chapter 2 are cemented onto permanent structures or areas not likely to be disturbed so that they may be referenced in the future with a high degree of accuracy. Usually these monuments are located on the land and/or on the cap of the breakwater (e.g., lighthouse bases) and used for horizontal and vertical references with respect to national datums. In addition to typical land survey methods, GPS coordinates are recorded for each monument and/or control point location. Other control points are located along the breakwater for use in determining armor movement and/or subsidence. Control points are usually located on large stable armor in the form of a monument, but occasionally something as simple as a nail embedded into the armor or a marked drill hole is used.

Another use for the ground-truth surveys has been to rectify photogrammetry (not used in the 2006 walking inspections). For this Periodic Inspection, previous surveys were used (a) for direct comparisons to current monitoring efforts, (b) to establish new control points at Burns Harbor, and (c) to validate the lidar elevation data.

4.2 Detailed walking inspections

Detailed walking inspections provide a relatively low-cost, expedient analysis of the performance of breakwater armor in its environment relative to past monitoring. Walking inspections also reveal details often unavailable through aerial photography or lidar, such as undermining and/or deterioration of the underlayer. Also, broken armor unit walking inspections are significantly more accurate than aerial or boat surveys.

During July 2006, a detailed walking inspection of the eastern 4,400 ft dolosse section of Cleveland Harbor East Breakwater was conducted. The stone armor section was not included during this particular inspection.

During August 2006, a detailed walking inspection of the Burns Harbor North Breakwater was conducted. (The Burns Harbor East Breakwater was also inspected at this time, but since this breakwater has not previously been a part of the Periodic Inspections work unit, those data are not included as part of this report).

Voids, depressions, undermining, and steep slopes were recorded. Significantly damaged armor units and stones were the primary focus of this effort. For armor units or stones to be considered significantly damaged, they had to be cracked throughout or broken. Each broken armor stone was recorded to include the approximate station number location, distance from the breakwater center line, and GPS coordinates. Photographs were taken of each, and a database established at CHL. Hairline fractures and spalling were often noted but were not recorded by this monitoring effort.

4.3 Light detection and ranging (lidar)

The JALBTCX performs operations, research, and development in airborne lidar bathymetry and topographic surveys, and complementary technologies for the purpose of coastal mapping and charting. The National Coastal Mapping Program (NCMP) supports the USACE requirement for regional management of coastal projects by collecting recurrent surveys along the sandy-shorelines. The NCMP collects high resolution lidar bathymetry and topography, hyperspectral imagery, and aerial photographs using the Coastal Zone Mapping and Imaging Lidar (CZMIL) system (Tuell et al. 2010; Reif et al. 2013; Wozencraft 2013). The CZMIL is the third generation integrated airborne sensor suite that represents the latest technology for improved coastal mapping and includes a lidar sensor, hyperspectral imager, and aerial digital camera system.

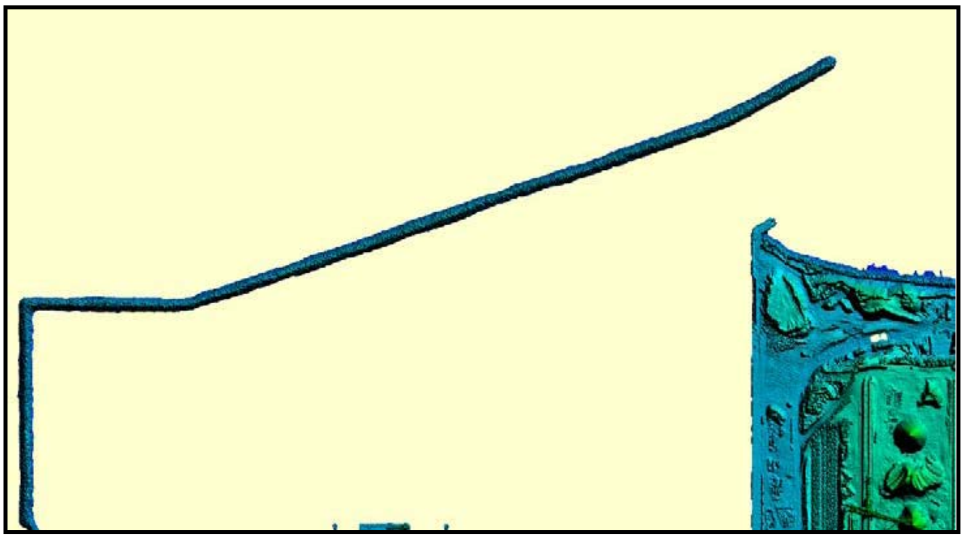
The lidar sensor uses a blue-green laser for improved water penetration and is a waveform-resolving system with a segmented detector array resulting in seven waveforms on land and water. The short laser pulse-length, high laser power, and a circular scan pattern result in improved coastal mapping in shallow, turbid waters. In addition, the circular scan pattern generates a forward and backward measurement in water that increases breaking wave penetration and water column property detection. Vertical accuracy on land and water is 9.25 centimeters (cm) root mean square error (RMSE) and 15 cm RMSE, respectively. Nominal point spacing (NPS) is 0.7 meters (m) on land and shallow water and is 2 m in optically deep water (Tuell et al. 2010; Wozencraft 2013).

A Compact Airborne Spectrographic Imager (CASI)-1500 hyperspectral imager is included on the sensor suite and can collect up to 288 spectral bands at 1.9 nanometer intervals resulting in 1 to 2 m spatial resolution. The hyperspectral imagery supports feature detection and classification. In

addition, the CZMIL includes an aerial digital camera system (CS-4800) for acquisition of high spatial resolution imagery (5 cm).

For the purpose of this periodic inspections work, the JALBTCX systems collected both topography and surrounding underwater bathymetry. Figure 26 shows an example of a color fill plot of lidar data. The data in this figure are from Burns Harbor North Breakwater.

Figure 26. Lidar data from Burns Harbor North Breakwater, Portage, IN.



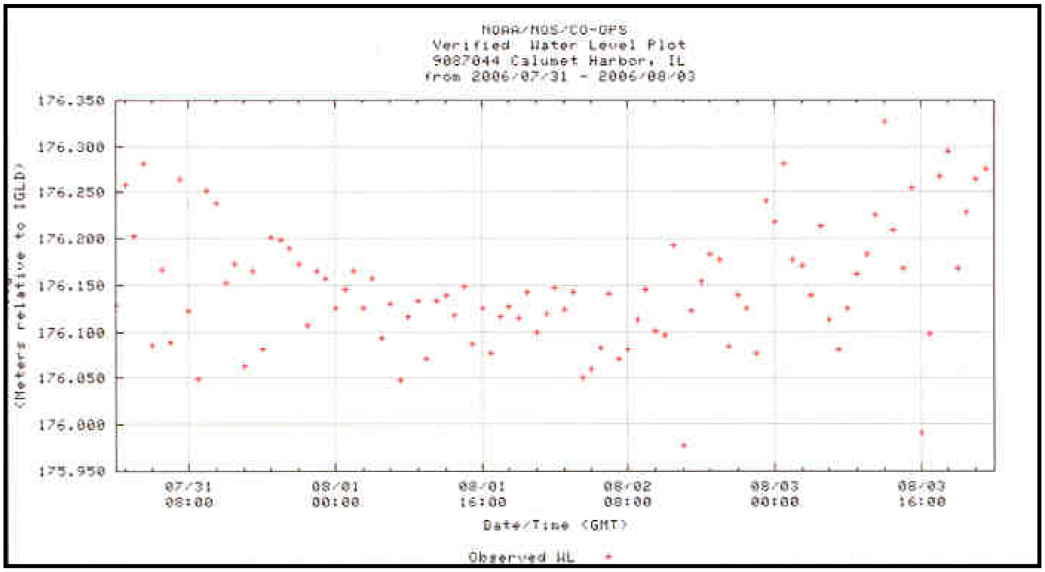
4.4 2006 Periodic Inspections walking inspections

4.4.1 Cleveland Harbor East Breakwater broken dolos walking inspection

During the detailed walking inspection of July 2006, 1,128 broken/cracked dolos armor units were identified above the waterline. Water levels during the walking inspection fluctuated very little with extremes of 571.5 to 571.8 ft IGLD85 and with an average of 571.7 ft IGLD85 (Figure 27). Water level data were obtained from NOAA wave gage number 9063063 located offshore of Cleveland, OH, at latitude 41^0 32.4’ N and longitude $81^0$38.1’ W.

Locations of damaged dolosse were referenced to station numbers beginning at the breakwater head and to the breakwater center line, except in cases where the dolosse were on the water’s edge. GPS coordinates were associated with each dolos.

Figure 27. Water level (m) time history from NOAA offshore gauge 9063063, Cleveland Harbor East Breakwater, July 2006 detailed walking inspection.



Of the 1,128 broken/cracked dolosse, 32 were from around the head with the remaining 1,096 along the trunk of the East Breakwater dolos section, and almost all were on the lake side. A distribution chart can be seen in Figure 28. Station numbers were measured with a tape for accuracy, often relying on older station marks for validation.

Figure 28. Distribution of damaged dolos armor units along Cleveland Harbor East Breakwater relative to station number, July 2006 detailed walking inspection.

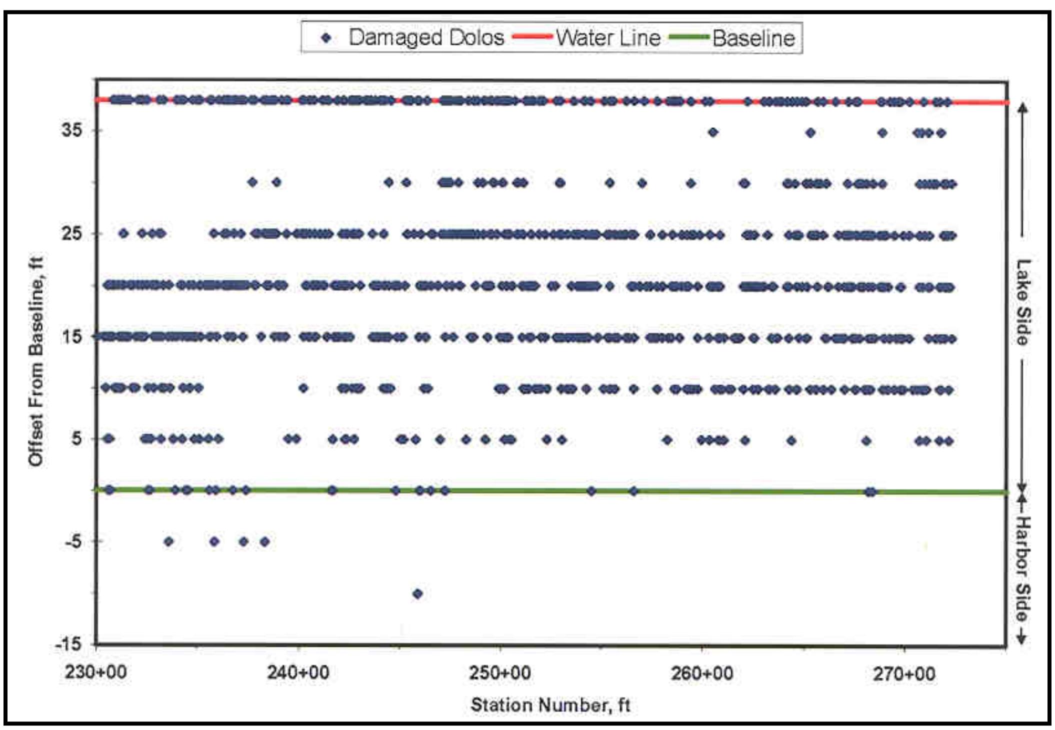
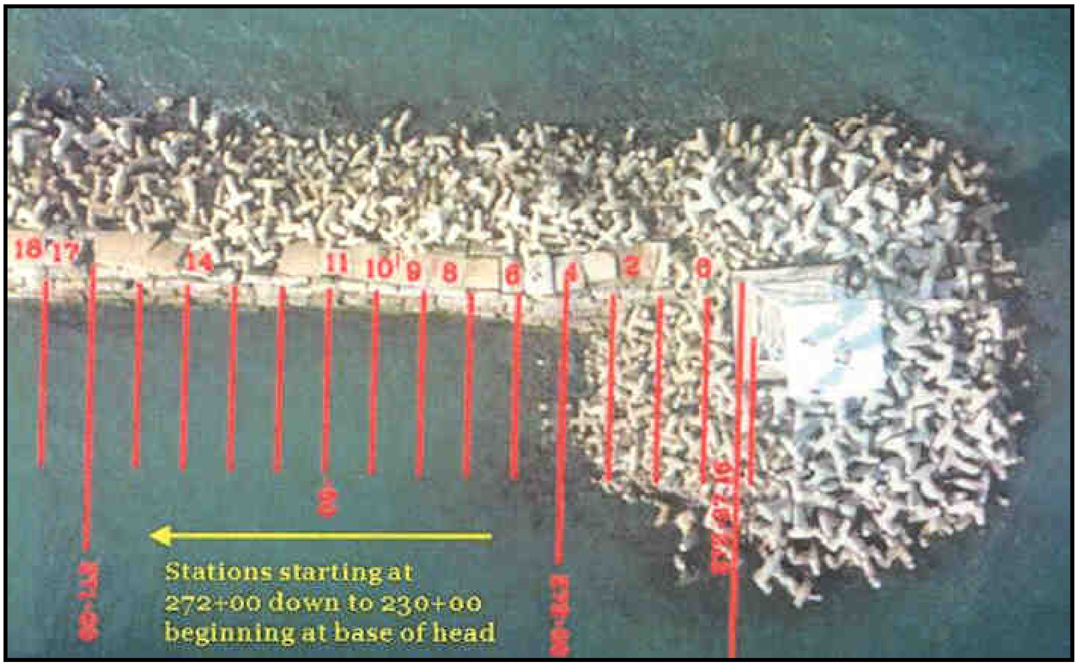


Figure 29 shows an aerial photograph and layout example of station marks on the Cleveland Harbor East Breakwater. Dolos distances from the center line were estimated on 5 ft intervals. A handheld Garmin GPS unit was used to take latitude, longitude, and elevation coordinates for each damaged dolos. This provided approximate location measurements and was used to determine the efficacy of this process for future monitoring as well as to provide a baseline for the Periodic Inspections GIS.

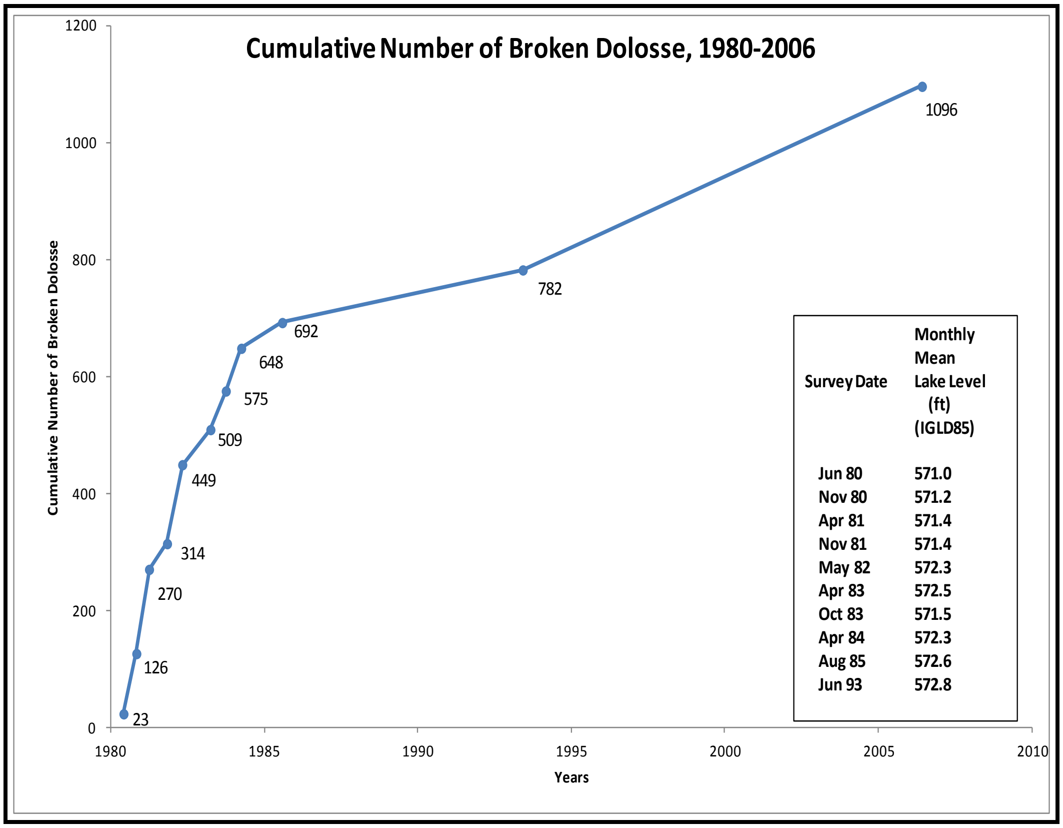
Figure 29. Example of station number layout for Cleveland Harbor East Breakwater.



Of the 1,128 damaged dolos units, 171 were found to have multiple breaks/cracks. Thirty-two of the 171 were in pieces. This is significant for comparison purposes because the 1993 monitoring did not count dolosse broken into pieces. The number of comparable multiple breaks for 2006 is 139 versus 48 in 1993, and the overall number of damaged dolosse is 1,096 for the 2006 walking inspection versus 782 in 1993. These data are shown in Figure 30 for the intervening 13 yr between 1993 and 2006.

With 692 broken/cracked dolosse in 1985, 782 in 1993, and 1,096 comparable dolosse in 2006, it appears the rate of breakage has somewhat increased. The 8 yr difference between 1985 and 1993 yielded an average of 11.25 new broken units per year, while the 13 yr difference between 1993 and 2006 showed an average of 24.1 new broken units per year, more than double.

Figure 30. Cumulative number of broken dolos armor units, including July 2006 detailed walking inspection, Cleveland Harbor East Breakwater.



The types of breaks are categorized into 13 detailed groups, more than previous studies. The damage groups include

1. straight shank
2. strait mid-shank
3. angled shank
4. angled mid-shank
5. cracked shank
6. straight fluke
7. straight fluke tip
8. angled fluke
9. angled fluke tip
10. cracked fluke
11. damaged fluke
12. damaged/broken fluke tip
13. pieces.

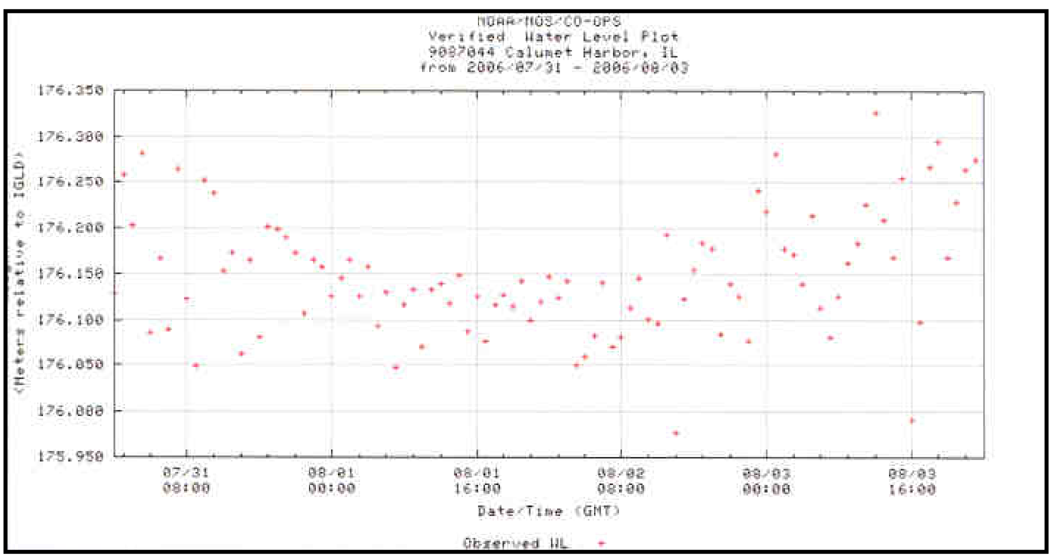
A vast majority of breaks occurred along the dolos shank. The total number of shank breaks, including multiple breaks, was 1,873. Fluke breaks only accounted for 470 of the total. Pieces accounted for the other 31 breaks, but they were counted as whole unit breaks, not multiple.

A complete list of broken/damaged dolosse, and their locations relative to GPS coordinates, station number, and estimated distance from the breakwater center line, can be seen in Appendix A.

4.4.2 Burns Harbor North Breakwater broken stone walking inspection

The detailed walking inspection of Burns Harbor North Breakwater revealed 282 broken/cracked armor stones. Water levels during the walking inspection fluctuated very little with extremes of 577.4 to 578.4 ft IGLD85 and with an average of 577.9 ft IGLD85 (Figure 31). Water level data were obtained from NOAA wave gage number 9087044 located offshore of Calumet Harbor, IL, at latitude 41o48.8' N and longitude 87o32.3' W.

Figure 31. Water level (m) time-history from NOAA offshore gauge 9087044, Burns Harbor North Breakwater, August 2006 detailed walking inspection.



There were five types of stone identified during the walking inspection that had sustained damage:

1. granite
2. dolomite
3. quartzite

4. Indiana Bedford limestone
5. smaller blocks of limestone that could not be verified as Bedford limestone.

Of the 282 damaged armor stones noted, 46 (16%) were granite, 84 (%) were dolomite, 2 (1%) were quartzite, 136 (48%) were Indiana Bedford limestone, and 14 (5%) were the unidentifiable limestone. Twenty-two of the damage locations were situated along the crest of the breakwater, 150 on the lake side of the structure and 110 on the harbor side of the structure. A distribution of the damage location referred to the centerline can be seen in Figure 32. Figure 33 shows the locations of the damaged stones recorded with the handheld GPS unit overlain on NOAA Nautical Chart 14905_4. Figure 34 is a photograph of the breakwater looking east that was taken during the walking inspection. A complete list of the damaged armor stones, with GPS locations and station numbers, can be found in the Appendix B.

Of the 282 damaged stones, 195 were found to have split completely through, and 17 were noted as pieces, where stones had eroded and been damaged to the point that no substantial pieces of stone were left. During the 1999 walking inspection, 225 broken stones had been documented over the same reach.

Figure 32. Distribution of damaged stone armor units along Burns Harbor North Breakwater relative to station number, August 2006 detailed walking inspection.

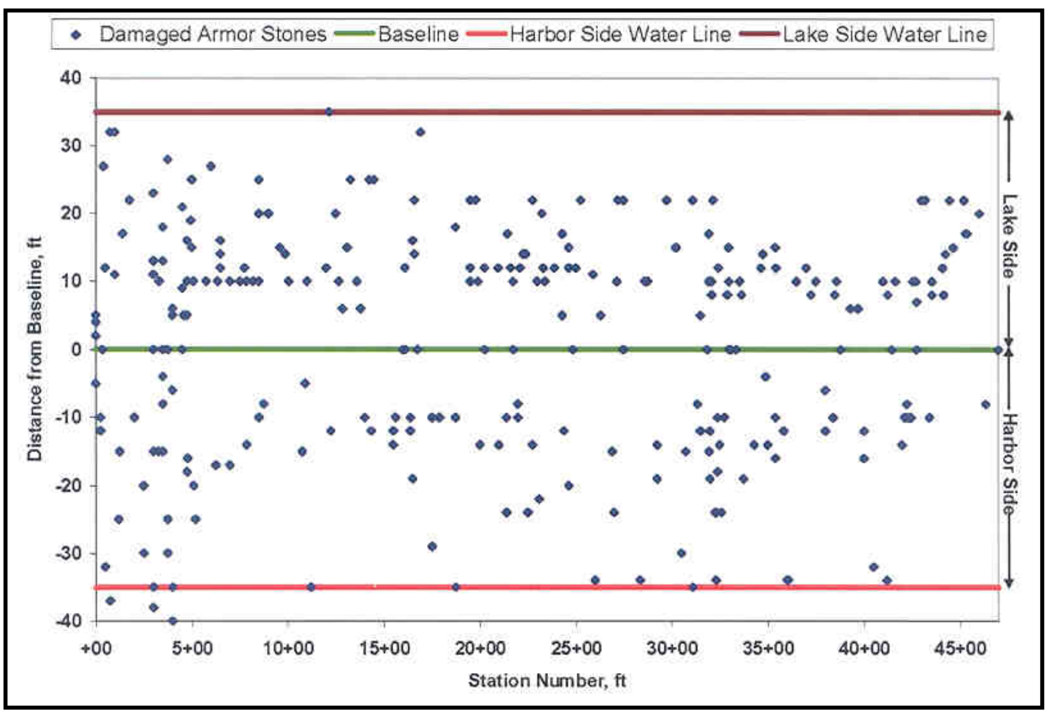


Figure 33. Locations of broken armor stones along Burns Harbor North Breakwater, August 2006 detailed walking inspection.

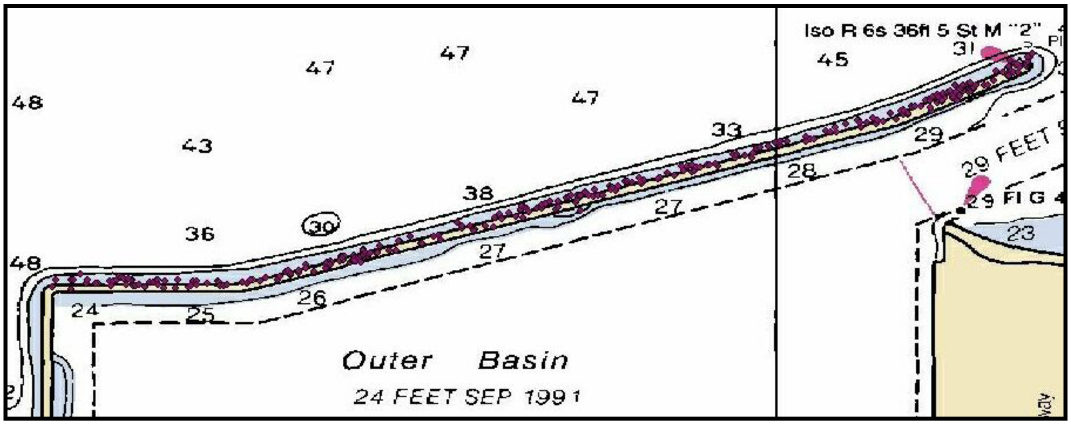


Figure 34. Burns Harbor North Breakwater looking east, August 2006 detailed walking inspection.

5 Summary and Conclusions

The MCNP Program was established to evaluate structural and functional performance of existing navigation structures. Under the Periodic Inspections work unit (a part of MCNP), aerial photography, ground-truth surveys, walking inspections, photogrammetry, and lidar are used to assess the structural conditions of select structures. A database of the existing data on all Periodic Inspections structures has been compiled to centralize data.

Cleveland Harbor East Breakwater, OH, has sustained extensive damage since its original construction was completed in 1915. The East Breakwater has had an extensive repair and rehabilitation history, including a major rehabilitation in 1979–80 that involved the placement of 2-ton dolosse on the lakeward slope and damaged crest of the easterly 4,400 ft. Some of these failed and were later replaced with 4-ton dolosse. Other recent repairs to the East Breakwater took place in 1986, 1989, 1991, and 2001 on the nondolos sections.

Burns Harbor North Breakwater, IN, is a 4,640 ft rubble-mound structure with an east-west alignment originally constructed in 1969. The North Breakwater has required extensive maintenance during its lifetime, including the addition of 290 kilotons of stone from original construction until 1989. A submerged reef breakwater system was constructed between 1995 and 1998, 75 ft lakeward of the existing North Breakwater for the purpose of reducing wave energy reaching the existing breakwater.

Monitoring of dolosse and armor stone through walking surveys and inspections has provided useful insight concerning the performance of the structures and the need of future rehabilitation efforts. Current monitoring included ground-truth surveys, detailed walking inspections, and the use of lidar technology. Records indicate that 1,128 broken and/or cracked dolosse, and 282 damaged armor stones, were documented during the 2006 inspection of Cleveland Harbor East Breakwater and Burns Harbor North Breakwater, respectively.

This interim data report contains a precise record of dolos and stone armor damage existing on these structures in July 2006. A comprehensive

analysis and technical report correlating this damage with storm and water level conditions will be published at a later date as subsequent additional field data is obtained at these two Great Lakes breakwaters.

Periodic inspection and monitoring of these structures should continue and will provide insight into the overall performance of each structure as originally designed and constructed. Monitoring will also document the benefits gained from structural maintenance, rehabilitation, and repairs.

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Appendix A: Broken/Damaged Dolos Armor Units (Type of Breaks and Locations) on the Cleveland Harbor East Breakwater, July 2006 Walking Inspection

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
1				1												41 32.589	81 39.081
2				1												41 32.591	81 39.079
3													1			41 32.586	81 39.077
4													1			41 32.586	81 39.078
5													1			41 32.586	81 39.080
6			1													41 32.591	81 39.077
7												1				41 32.591	81 39.076
8											1					41 32.590	81 39.074
9			1			1					1					41 32.589	81 39.070
10										1						41 32.584	81 39.070
11									1							41 32.582	81 39.071
12													1			41 32.580	81 39.071
13						1										41 32.581	81 39.072
14						1										41 32.583	81 39.072
15			1													41 32.578	81 39.076
16								1								41 32.578	81 39.076
17								1								41 32.579	81 39.079
18	1															41 32.578	81 39.079
19								1								41 32.579	81 39.079
20			1			1										41 32.583	81 39.079
21													1				
22													1			41 32.582	81 39.080
23			1					1								41 32.586	81 39.082

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
24			1													41 32.584	81 39.080
25													1			41 32.585	81 39.079
26			1													41 32.586	81 39.079
27	1															41 32.587	81 39.081
28						1										41 32.586	81 39.083
29			1			1										41 32.587	81 39.083
30								2								41 32.582	81 39.071
31						1										41 32.580	81 39.070
32								2						272+30	30	41 32.587	81 39.083
33			1													41 32.579	81 39.072
34			1											272+30	25	41 32.586	81 39.085
35			1											272+30	15	41 32.585	81 39.083
36			1											272+15	5		
37						1								272+15	10	41 32.585	81 39.086
38						1		1						272+10	25	41 32.584	81 39.084
39	1													272+05	25	41 32.586	81 39.086
40	1													272+00	30	41 32.585	81 39.087
41	1													272+05	38	41 32.585	81 39.087
42								2						272+05	20	41 32.586	81 39.086
43								1						272+05	30	41 32.586	81 39.088
44								1						272+05	38	41 32.586	81 39.088
45						1								272+00	20		
46	1							1						272+20	20	41 32.585	81 39.087

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
47			1											nd	nd	41 32.582	81 39.087
48	1													271+95	20	41 32.584	81 39.087
49	1													271+95	15	41 32.583	81 39.087
50								1						271+90	25	41 32.583	81 39.089
51								1						271+90	25	41 32.584	81 39.090
52								1						271+90	30	41 32.584	81 39.090
53			1											217+80	35	41 32.583	81 39.091
54			1											217+80	38	41 32.582	81 39.090
55			1											217+80	35	41 32.583	81 39.092
56						2								271+75	35	41 32.583	81 39.091
57	1													271+75	15	41 32.582	81 39.090
58			1					1						271+75	10	41 32.582	81 39.090
59			1											271+70	10	41 32.581	81 39.091
59A								1						271+70	38		
60			1											271+70	5	41 32.580	81 39.091
61								1						271+70	20	41 32.581	81 39.093
62		1												271+75	20	41 32.582	81 39.092
63													1	217+80	20	41 32.582	81 39.091
64										1				271+50	15	41 32.579	81 39.092
65					1									271+50	15	41 32.580	81 39.094
66			1											271+50	30	41 32.581	81 39.096
67			1											271+50	30	41 32.580	81 39.097
68		1												271+50	38	41 32.582	81 39.097

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
69			1											271+20	20	41 32.577	81 39.098
70			1											271+20	20	41 32.576	81 39.099
71				1										271+20	25	41 32.579	81 39.099
72				1										271+20	30	41 32.578	81 39.098
73	1													271+40	30	41 32.579	81 39.098
74				1										271+20	25	41 32.576	81 39.100
75			1											271+50	30	41 32.579	81 39.098
76													1	271+20	30	41 32.577	81 39.100
77			1											271+15	35	41 32.578	81 39.100
78													1	271+15	20	41 32.577	81 39.100
79								1						271+15	15	41 32.577	81 39.100
80			1											271+05	10	41 32.577	81 39.101
81			1			1								271+05	5	41 32.574	81 39.102
82								1						270+95	30	41 32.576	81 39.104
83				1										270+95	25	41 32.574	81 39.107
84						1								270+85	20	41 32.575	81 39.106
85										1				270+85	10	41 32.573	81 39.106
86	1													270+85	10	41 32.574	81 39.104
87	1													270+70	20	41 32.574	81 39.108
88			1											270+70	25	41 32.573	81 39.108
89	1													270+70	20	41 32.572	81 39.109
90					1									270+70	5	41 32.571	81 39.108
91			1											270+60	10	41 32.571	81 39.109

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
92	1				1					1				270+95	10	41 32.573	81 39.104
93								2						270+90	38		
94						1								270+80	35	41 32.572	81 39.113
95						1								270+70	30	41 32.572	81 39.113
96								1						270+60	10	41 32.571	81 39.112
97								1						270+60	35	41 32.572	81 39.116
98													1	270+40	10	41 32.570	81 39.114
99						1								270+20	15	41 32.569	81 39.117
100				1										270+20	25	41 32.569	81 39.117
101			1											270+20	38	41 32.569	81 39.118
102	1													270+20	38	41 32.569	81 39.117
103			1			1								269+90	10	41 32.566	81 39.120
104	1													269+90	10	41 32.567	81 39.120
105			1											269+90	10	41 32.567	81 39.120
106	1													269+90	15	41 32.567	81 39.120
107			1											269+90	25	41 32.568	81 39.120
108			1											269+90	25	41 32.566	81 39.120
109								1						269+90	25	41 32.570	81 39.119
110	1													269+90	10	41 32.565	81 39.120
111	1													269+90	15	41 32.565	81 39.122
112	1					1								269+80	10	41 32.565	81 39.123
113			1											269+80	15	41 32.565	81 39.123
114	1													269+80	20	41 32.566	81 39.122

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
115			1											269+75	20	41 32.565	81 39.124
116			1											269+75	38	41 32.565	81 39.124
117													1	269+75	15	41 32.564	81 39.125
118	1													269+65	38	41 32.563	81 39.126
119	1													269+55	15	41 32.563	81 39.127
120	1													269+45	10	41 32.561	81 39.129
121			1											269+45	25	41 32.562	81 39.131
122			1					1						269+45	38		
123								1						269+45	25		
124			1					1						269+25	15	41 32.558	81 39.134
125			1					1						269+25	15	41 32.559	81 39.134
126	1													269+25	38	41 32.560	81 39.133
127			1											269+15	20	41 32.558	81 39.137
128	1					1								269+15	20	41 32.557	81 39.137
129			1			1								269+15	10	41 32.557	81 39.136
130						1								269+05	25	41 32.557	81 39.138
131						1								268+95	15	41 32.556	81 39.138
132				1										268+95	20	41 32.556	81 39.139
133	1													268+90	20	41 32.556	81 39.139
134		1												268+95	25	41 32.557	81 39.139
135						1								268+95	25	41 32.556	81 39.140
136			1											268+85	30	41 32.555	81 39.140
137						1								268+85	35	41 32.555	81 39.142

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
138	1													268+85	35	41 32.554	81 39.138
139			1											268+90	10	41 32.555	81 39.141
140			1											268+85	38	41 32.554	81 39.141
141						1								268+80	20	41 32.554	81 39.142
142			1											268+75	20	41 32.554	81 39.141
143			1											268+75	25	41 32.552	81 39.143
144			1					1						268+50	15	41 32.551	81 39.145
145						1								268+40	20	41 32.550	81 39.144
146	1													268+40	0	41 32.550	81 39.147
147	1													268+40	0	41 32.551	81 39.148
148				1										268+35	15	41 32.549	81 39.148
149	1													268+40	25		
150						1								268+30	10		
151								1						268+30	25		
152			1											268+40	30		
153						1								268+20	25	41 32.550	81 39.150
154	1													268+30	25	41 32.551	81 39.150
155	1													268+20	20	41 32.548	81 39.150
156						1								268+20	15	41 32.547	81 39.150
157						1								268+20	15	41 32.548	81 39.149
158	1					1								268+20	10	41 32.547	81 39.151
159			1											268+10	5	41 32.546	81 39.151
160						1								268+05	10	41 32.547	81 39.152

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
161			1											268+05	25	41 32.547	81 39.153
162	1													268+10	25	41 32.548	81 39.153
163			1											268+10	30	41 32.548	81 39.154
164	1													268+20	0		
165								1						268+00	10	41 32.546	81 39.152
166			1											267+95	25	41 32.546	81 39.154
167								1						267+90	25	41 32.547	81 39.155
168			1					1						267+95	25	41 32.547	81 39.154
169				1										267+90	25	41 32.548	81 39.154
170	1													267+90	20	41 32.547	81 39.154
171	1													267+80	20	41 32.544	81 39.158
172	1													267+75	20	41 32.548	81 39.156
173	1													267+95	20	41 32.546	81 39.156
174								1						267+90	30	41 32.547	81 39.157
175	1													267+75	30	41 32.545	81 39.158
176			1											267+65	30	41 32.544	81 39.160
177								1						267+75	15	41 32.544	81 39.157
178			1											267+65	25	41 32.544	81 39.158
179	1													267+65	30	41 32.543	81 39.159
180	1													267+65	25	41 32.544	81 39.159
181								1						267+65	38	41 32.544	81 39.159
182								1						267+20	20	41 32.542	81 39.160
183			1			1								267+55	10	41 32.541	81 39.161

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
184	1													267+55	25	41 32.540	81 39.162
185	1					1								267+55	10	41 32.540	81 39.161
186	1													267+55	38		
187								1						267+40	15	41 32.540	81 39.163
188			1											267+40	20	41 32.540	81 39.163
189			1					1						267+50	15	41 32.540	81 39.161
190								1						267+55	15	41 32.541	81 39.161
191	1													267+55	15	41 32.541	81 39.161
192	1													267+40	20	41 32.540	81 39.163
193			1											267+30	20	41 32.540	81 39.165
194				1										267+20	20	41 32.539	81 39.164
195				1										267+30	25	41 32.540	81 39.165
196	1													267+20	20	41 32.539	81 39.165
197	1													267+20	25	41 32.539	81 39.166
198	1													267+15	25		
199	1													267+20	38	41 32.538	81 39.167
200			1			1								267+15	20	41 32.538	81 39.167
201								1						267+20	25		
202													1	267+15	30		
203	1													267+00	10	41 32.537	81 39.167
204			1											267+00	15	41 32.536	81 39.170
205	1													267+00	25	41 32.537	81 39.168
206	1													267+00	20	41 32.537	81 39.169

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
207	1													267+15	25		
208	1													266+90	15	41 32.535	81 39.172
209						1								266+70	15	41 32.534	81 39.173
210								1						267+00	25	41 32.537	81 39.171
211			1											266+70	15	41 32.535	81 39.173
212								1						266+70	15	41 32.532	81 39.174
213	1							1						266+70	15	41 32.534	81 39.173
214			1					1						266+70	20	41 32.535	81 39.174
215								1						266+70	25	41 32.535	81 39.174
216								1						266+70	20	41 32.535	81 39.173
217			1					1						266+70	25	41 32.536	81 39.173
218			1					1						266+70	25		
219			1											266+70	20	41 32.533	81 39.176
220								1						266+55	15	41 32.534	81 39.175
221	1					1								266+55	38	41 32.534	81 39.176
222						1								266+35	10	41 32.532	81 39.180
223								2						266+35	10	41 32.530	81 39.180
224			1											266+20	20	41 32.531	81 39.182
225			1											266+05	15	41 32.531	81 39.178
226	1													266+05	15	41 32.530	81 39.180
227			1											266+10	15	41 32.530	81 39.182
228	1													266+10	30		
229			1											265+95	10	41 32.529	81 39.181

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
230		1												265+95	25	41 32.528	81 39.186
231	1													265+95	25	41 32.529	81 39.185
232	1													265+95	25	41 32.530	81 39.183
233								1						265+95	25	41 32.528	81 39.187
234								2						265+95	25		
235			1											265+95	38		
236								1						265+80	30	41 32.529	81 39.189
237			1											265+80	30	41 32.529	81 39.189
238						1		1						265+65	38	41 32.526	81 39.190
239	1													265+65	20	41 32.525	81 39.191
240			1											265+65	25	41 32.525	81 39.191
241			1					1						265+65	25	41 32.525	81 39.191
242								1						265+60	30		
243								1						265+60	10	41 32.523	81 39.191
244						1								265+65	25	41 32.524	81 39.193
245								1						265+65	20	41 32.525	81 39.192
246			1					1						265+65	20	41 32.524	81 39.194
247			1											265+50	25	41 32.523	81 39.195
248			1											265+65	30	41 32.523	81 39.195
249	1													265+65	38		
250	1					1								265+35	25	41 32.521	81 39.195
251												1		265+30	30	41 32.523	81 39.198
252			1											265+30	10	41 32.521	81 39.198

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
253								1						265+30	35		
254	1													265+15	15	41 32.519	81 39.200
255	1													265+15	20	41 32.519	81 39.202
256													1	265+10	30	41 32.518	81 39.202
257								1						265+10	38	41 32.519	81 39.201
258			1											265+10	15	41 32.518	81 39.203
259	1													265+10	38	41 32.519	81 39.201
260			1											264+90	20	41 32.517	81 39.205
261								1						264+90	38	41 32.517	81 39.205
262			1											264+75	15	41 32.517	81 39.204
263	1													264+75	25		
264	1		1											264+70	25	41 32.514	81 39.206
265			1											264+75	25		
266	1													264+65	10	41 32.513	81 39.207
267			1											264+65	20	41 32.517	81 39.206
268	1													264+65	20	41 32.512	81 39.209
269								1						264+65	20	41 32.514	81 39.208
270								1						264+55	25	41 32.514	81 39.210
271								1						264+65	38	41 32.514	81 39.212
272						1								264+65	38		
273			1											264+55	30	41 32.511	81 39.215
274			1											264+55	30	41 32.511	81 39.215
275			1											264+40	38	41 32.511	81 39.214

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
276	1													264+40	38	41 32.511	81 39.214
277	1													264+40	5	41 32.509	81 39.214
278	1													264+25	10	41 32.507	81 39.216
279								1						264+25	15	41 32.509	81 39.215
280								1						264+25	20	41 32.511	81 39.214
281								1						264+25	30	41 32.510	81 39.218
282								1						264+25	25	41 32.510	81 39.218
283								1						264+15	38	41 32.510	81 39.218
284						1								264+15	30	41 32.509	81 39.219
285						1								264+15	20	41 32.509	81 39.218
286								1						263+90	38	41 32.506	81 39.223
287								1						263+80	38	41 32.506	81 39.224
288	1													263+90	38	41 32.508	81 39.222
289	1													263+70	15	41 32.502	81 39.230
290								1						263+60	10		
291								1						263+60	38		
292			1											263+60	38		
293			1											263+50	20	41 32.504	81 39.229
294								2						263+40	20	41 32.500	81 39.234
295			1											263+40	15	41 32.499	81 39.235
296								1						263+65	15	41 32.505	81 39.227
297	1													263+40	15	41 32.500	81 39.234
298			1											263+30	10	41 32.496	81 39.237

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
299			1											263+25	10	41 32.497	81 39.236
300								1						263+20	25	41 32.498	81 39.238
301			1											263+25	38		
302								1						263+30	38	41 32.499	81 39.237
303	1													263+05	20	41 32.495	81 39.241
304								1						263+00	38	41 32.495	81 39.242
305			1											262+95	20	41 32.494	81 39.243
306			1											262+50	20	41 32.494	81 39.244
307								2						262+75	10	41 32.493	81 39.246
308	1													262+75	10	41 32.493	81 39.246
309						1								262+75	10	41 32.491	81 39.247
310					1					1				262+75	10	41 32.493	81 39.246
311	1		1											262+75	20	41 32.493	81 39.246
312	1							1						262+70	20	41 32.492	81 39.247
313						1								262+55	15	41 32.491	81 39.248
314			1											262+55	15	41 32.491	81 39.251
315			1											262+50	10	41 32.491	81 39.248
316								1						262+50	15	41 32.491	81 39.251
317								1						262+55	25	41 32.492	81 39.251
318	1							1						262+45	20		
319	1													262+55	25	41 32.491	81 39.252
320	1													262+35	25		
321	2													262+65	20	41 32.491	81 39.251

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
322			1					1						262+30	20	41 32.489	81 39.255
323	1		1											262+30	25		
324			1											262+10	5		
325			1											262+10	20	41 32.488	81 39.257
326	1			1		1								262+20	20	41 32.488	81 39.257
327			1											262+15	25	41 32.488	81 39.259
328			1											262+20	38		
329	1													262+00	30	41 32.486	81 39.261
330	1													262+00	20	41 32.485	81 39.260
331								1						262+10	30	41 32.487	81 39.259
332	1													262+00	30	41 32.484	81 39.261
333				1										262+00	20	41 32.483	81 39.261
334						2								262+00	10	41 32.483	81 39.260
335	1													261+85	15	41 32.481	81 39.264
336			1											261+85	15	41 32.482	81 39.264
337								2						261+75	15	41 32.482	81 39.267
338				2										261+65	15	41 32.481	81 39.268
339	2													261+65	15	41 32.481	81 39.267
340			1											261+55	15	41 32.481	81 39.269
341						1								261+40	10	41 32.479	81 39.271
342								1						261+40	10	41 32.478	81 39.272
343			1											261+30	10	41 32.479	81 39.272
344	1													261+05	15	41 32.472	81 39.280

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
345	1													260+95	10	41 32.474	81 39.280
346			1											261+05	5	41 32.474	81 39.278
347								1						260+85	15	41 32.472	81 39.281
348	1													260+85	10	41 32.471	81 39.282
349			1											260+80	5	41 32.471	81 39.282
350			1											260+85	20	41 32.472	81 39.283
351	1													260+85	25	41 32.472	81 39.282
352			1											260+75	15	41 32.471	81 39.284
353	2													260+70	20	41 32.471	81 39.284
354	1													260+70	20	41 32.472	81 39.284
355			1											260+70	20	41 32.472	81 39.284
356			1											260+60	10	41 32.470	81 39.285
357	1													260+50	35	41 32.469	81 39.289
358	1													260+50	20	41 32.468	81 39.288
359			1											260+35	5	41 32.466	81 39.289
360			1											260+35	5	41 32.466	81 39.289
361	1													260+40	20	41 32.468	81 39.290
362	1													260+45	20	41 32.468	81 39.291
363	1													260+35	20	41 32.467	81 39.292
364			1											260+35	25	41 32.467	81 39.291
365			1											260+30	15	41 32.467	81 39.295
366	1							1						260+35	38		
367	1													260+10	38	41 32.466	81 39.296

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
368			1											259+95	5	41 32.462	81 39.300
369	1													259+85	25	41 32.463	81 39.301
370			1											259+75	15	41 32.462	81 39.300
371			1											259+75	10	41 32.461	81 39.301
372								1						259+75	20	41 32.463	81 39.302
373						1								259+75	20	41 32.462	81 39.302
374	1													259+55	10	41 32.459	81 39.306
375			1											259+55	25	41 32.460	81 39.307
376			1											259+40	30	41 32.460	81 39.307
377	1													259+40	30	41 32.459	81 39.308
378	1													259+40	25	41 32.460	81 39.308
379								1						259+40	38	41 32.460	81 39.309
380			1											259+40	10		
381	1													259+40	25	41 32.459	81 39.310
382								1						259+30	20	41 32.457	81 39.311
383			1											259+20	10	41 32.456	81 39.311
384			1					1						259+20	20	41 32.456	81 39.313
385			1											259+20	20	41 32.455	81 39.313
386												1		259+30	10	41 32.452	81 39.310
387			1											259+20	25	41 32.456	81 39.313
388	1													259+20	25	41 32.455	81 39.312
389			1											259+20	25		
390	1							1						259+20	20	41 32.455	81 39.314

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
391	1													258+85	15	41 32.454	81 39.315
392								1						258+85	15	41 32.454	81 39.315
393	1							1						258+95	20	41 32.454	81 39.316
394	1													258+95	25		
395			1											258+85	15	41 32.453	81 39.316
396			1											258+85	15	41 32.454	81 39.316
397			1											268+75	38	41 32.454	81 39.317
398								1						258+85	38	41 32.455	81 39.315
399	1													268+75	38	41 32.454	81 39.318
400			1											258+70	10	41 32.450	81 39.317
401								2						258+60	10	41 32.449	81 39.319
402			1											258+70	20	41 32.453	81 39.319
403		1												258+70	38	41 32.451	81 39.320
404						1								258+50	38	41 32.451	81 39.323
405												1		258+60	38	41 32.451	81 39.323
406	1													258+50	20	41 32.450	81 39.322
407								2						258+60	20	41 32.450	81 39.322
408			1											258+50	25	41 32.450	81 39.321
409	1					1								258+50	20	41 32.450	81 39.322
410	1													258+45	20	41 32.450	81 39.323
411								1						258+45	15	41 32.449	81 39.323
412			1											258+25	5	41 32.447	81 39.326
413	1													258+30	15	41 32.448	81 39.326

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
414	1													258+30	38	41 32.448	81 39.326
415	1													258+30	38	41 32.448	81 39.325
416	1													258+30	38	41 32.448	81 39.325
417	1													258+00	15	41 32.445	81 39.333
418								1						258+00	15	41 32.444	81 39.333
419						1								258+00	25	41 32.445	81 39.333
420								1						258+00	20	41 32.445	81 39.333
421			1											257+75	10	41 32.442	81 39.336
422	1													257+75	15	41 32.442	81 39.336
423						1								257+75	15	41 32.442	81 39.336
424	1													257+75	38	41 32.443	81 39.335
425	1													257+75	20	41 32.443	81 39.335
426								1						257+75	20	41 32.442	81 39.335
427								1						257+60	15	41 32.440	81 39.339
428	1													257+40	25	41 32.441	81 39.340
429	1							1						257+40	25	41 32.442	81 39.340
430						1								257+40	20		
431			1											257+40	15	41 32.441	81 39.340
432								2						257+40	25	41 32.440	81 39.341
433			1									1		257+20	20	41 32.438	81 39.347
434		1												257+10	38	41 32.437	81 39.347
435			1											257+00	30	41 32.435	81 39.351
436	1													256+85	20	41 32.434	81 39.352

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
437			1											256+60	0	41 32.430	81 39.352
438				1										256+60	10	41 32.431	81 39.353
439			1											256+60	15	41 32.431	81 39.353
440			1					1						256+60	10	41 32.431	81 39.354
441								1						256+60	10	41 32.431	81 39.357
442								1						256+60	15	41 32.431	81 39.357
443	1													256+60	20	41 32.431	81 39.357
444						1								256+50	20	41 32.431	81 39.358
445	1													256+90	20	41 32.432	81 39.355
446			1											256+60	20		
447	1													256+60	20	41 32.431	81 39.358
448	1													256+60	25	41 32.432	81 39.357
449													1	256+60	38		
450								1						256+45	20	41 32.430	81 39.359
451			1											256+45	25	41 32.431	81 39.359
452	1													256+35	15	41 32.429	81 39.359
453	1													256+20	25	41 32.429	81 39.362
454			1											256+20	38	41 32.429	81 39.364
455	1													256+20	15	41 32.427	81 39.364
456			1											256+10	25	41 32.427	81 39.366
457			1					1						255+90	25	41 32.426	81 39.366
458	1													255+90	25	41 32.426	81 39.367
459										1				255+80	15	41 32.423	81 39.370

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
460				1										255+90	25	41 32.426	81 39.368
461			1											255+65	15	41 32.424	81 39.371
462			1											255+90	25		
463								2						255+65	10	41 32.423	81 39.371
464	1				1	1								255+65	25	41 32.424	81 39.372
465	1													255+40	15	41 32.421	81 39.374
466						1								255+55	38		
467	1													255+40	15	41 32.420	81 39.377
468								1						255+40	10	41 32.421	81 39.376
469			1											255+40	25	41 32.420	81 39.377
470			1			1								255+40	25	41 32.420	81 39.378
471	1													255+40	38	41 32.420	81 39.378
472	1													255+40	25	41 32.420	81 39.378
473								1						255+40	20	41 32.420	81 39.377
474	1													255+30	15	41 32.418	81 39.378
475			1											255+40	25	41 32.419	81 39.379
476	1													255+40	30	41 32.417	81 39.372
477			1											255+10	10	41 32.417	81 39.377
478				1										255+25	25	41 32.417	81 39.385
479	1													255+25	25	41 32.414	81 39.387
480						1								255+10	38	41 32.417	81 39.387
481			1					1						254+80	15	41 32.413	81 39.388
482	1													254+75	20	41 32.412	81 39.388

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
483		1												254+65	25	41 32.413	81 39.389
484			1											254+60	20	41 32.411	81 39.390
485	1					1								254+75	25	41 32.413	81 39.388
486								1						254+55	20	41 32.410	81 39.392
487	1													254+50	0	41 32.408	81 39.393
488	1													254+45	20	41 32.410	81 39.393
489				1										254+55	25	41 32.411	81 39.393
490								1						254+45	25	41 32.411	81 39.395
491			1											254+45	38		
492						1								254+35	15	41 32.408	81 39.395
493			1											254+35	20	41 32.408	81 39.396
494								2						254+25	20	41 32.408	81 39.397
495								1						254+25	25	41 32.409	81 39.398
496			1											254+25	10		
497			1					1						254+20	20	41 32.407	81 39.398
498	1													254+20	15	41 32.406	81 39.397
499	1							1						254+20	20	41 32.408	81 39.399
500	1													254+20	20	41 32.408	81 39.399
501								1						254+15	15	41 32.406	81 39.399
502	1													254+20	15	41 32.406	81 39.398
503			1											254+15	20	41 32.406	81 39.399
504								2						254+10	20	41 32.406	81 39.399
505	1							1						254+05	15	41 32.406	81 39.401

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
506								2						254+05	20	41 32.406	81 39.402
507	1													253+90	15	41 32.403	81 39.403
508			1											254+15	38	41 32.407	81 39.402
509								1						254+10	38	41 32.407	81 39.401
510						1								253+90	15	41 32.403	81 39.403
511	1													253+90	20	41 32.404	81 39.404
512								2						254+15	25		
513				1										253+80	20	41 32.405	81 39.405
514	1													253+80	15	41 32.403	81 39.405
515	1													253+90	25	41 32.405	81 39.404
516								1						253+90	20	41 32.404	81 39.404
517													1	253+80	25	41 32.404	81 39.406
518								1						253+70	25	41 32.403	81 39.409
519													1	253+60	38	41 32.403	81 39.410
520						1								253+60	25	41 32.402	81 39.409
521			1											253+60	15	41 32.401	81 39.409
522			1											253+50	20	41 32.401	81 39.410
523	1													253+55	10	41 32.400	81 39.409
524								1						253+40	10	41 32.399	81 39.412
525	1													253+40	15	41 32.399	81 39.412
526	1													253+30	10	41 32.397	81 39.415
527								1						253+30	15	41 32.398	81 39.416
528	1													253+30	25	41 32.398	81 39.415

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
529			1											253+05	5	41 32.394	81 39.418
530								1						253+00	10	41 32.395	81 39.419
531	1													253+05	15	41 32.395	81 39.419
532	1													253+05	25	41 32.395	81 39.419
533			1											252+95	25	41 32.396	81 39.420
534			1											252+90	25	41 32.396	81 39.421
535										1				252+95	30	41 32.397	81 39.421
536	1													252+90	30	41 32.396	81 39.421
537			1											252+90	15	41 32.393	81 39.421
538			1											252+75	15	41 32.393	81 39.421
539			1											252+90	25	41 32.395	81 39.422
540								1						252+70	20	41 32.394	81 39.424
541								1						252+75	38		
542			1											252+70	20	41 32.393	81 39.425
543	1													252+60	25	41 32.392	81 39.427
544								1						252+95	38	41 32.395	81 39.422
545								1						252+50	20	41 32.391	81 39.428
546	1													252+30	5	41 32.388	81 39.430
547			1											252+30	10	41 32.388	81 39.431
548			1											252+20	15	41 32.388	81 39.433
549								1						252+20	25	41 32.388	81 39.433
550								1						252+00	15	41 32.386	81 39.435
551													1	252+10	38	41 32.388	81 39.434

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
552			1			1								252+00	10	41 32.384	81 39.435
553	1													252+10	38	41 32.387	81 39.434
554													1	252+00	38	41 32.386	81 39.436
555								2						251+90	38	41 32.386	81 39.438
556			1											251+80	10	41 32.383	81 39.440
557			1											251+70	10		
558			1											251+90	25	41 32.385	81 39.439
559			1											251+70	20	41 32.382	81 39.441
560	1													251+90	38	41 32.386	81 39.439
561			1											251+70	20	41 32.383	81 39.441
562	1													251+90	38	41 32.385	81 39.439
563	1													251+60	20	41 32.382	81 39.442
564				1										251+90	38	41 32.385	81 39.439
565			1											251+60	38	41 32.382	81 39.443
566						1								251+50	38	41 32.382	81 39.442
567	1													251+70	20	41 32.385	81 39.440
568	1													251+60	20	41 32.381	81 39.444
569				1										251+50	25	41 32.381	81 39.444
570			1											251+50	20	41 32.381	81 39.444
571								1						251+40	10	41 32.379	81 39.444
572			1			1								251+40	15	41 32.378	81 39.445
573	1													251+60	38		
574										1				251+40	15	41 32.380	81 39.445

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
575	1													251+50	15	41 32.379	81 39.442
576	1													251+40	15	41 32.379	81 39.447
577	2													251+40	20	41 32.380	81 39.446
578	1													251+30	38	41 32.379	81 39.449
579			1											251+30	10	41 32.378	81 39.448
580				1										251+30	10	41 32.378	81 39.449
581	1													251+20	10	41 32.378	81 39.449
582				1										251+20	10	41 32.377	81 39.449
583				1										251+30	20	41 32.379	81 39.449
584								1						251+20	38	41 32.379	81 39.450
585								1						251+15	10		
586			1											251+10	10	41 32.377	81 39.450
587	1													251+10	10	41 32.376	81 39.452
588								1						251+10	20	41 32.377	81 39.452
589			1											251+05	15	41 32.376	81 39.452
590			1											251+05	20	41 32.377	81 39.453
591			1											251+05	25	41 32.377	81 39.454
592			1											251+10	25	41 32.376	81 39.454
593			1											251+10	30	41 32.376	81 39.455
594								1						251+10	30		
595			1											250+85	25	41 32.375	81 39.456
596	1													250+85	30	41 32.376	81 39.456
597								1						250+80	25	41 32.374	81 39.458

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
598								1						250+80	30	41 32.373	81 39.458
599	1							1						250+80	25	41 32.373	81 39.459
600	1													250+85	30	41 32.372	81 39.460
601			1					1						250+70	38		
602								1						250+55	20	41 32.372	81 39.462
603	1													250+55	5	41 32.370	81 39.463
604	1					1								250+45	5	41 32.369	81 39.463
605	1													250+45	25	41 32.370	81 39.465
606	1													250+45	25	41 32.371	81 39.464
607						1		1						250+40	25	41 32.371	81 39.464
608	1													250+40	15	41 32.369	81 39.465
609								1						250+35	38	41 32.371	81 39.465
610	1													250+30	15	41 32.369	81 39.466
611						1								250+40	38	41 32.371	81 39.464
612	1													250+25	15	41 32.369	81 39.467
613	1													250+30	25	41 32.370	81 39.467
614			1											250+35	38	41 32.370	81 39.467
615			1											250+30	20	41 32.370	81 39.466
616			1											250+30	38	41 32.367	81 39.468
617			1											250+20	25	41 32.368	81 39.469
618	1													250+20	5	41 32.367	81 39.467
619			1											250+20	10	41 32.367	81 39.469
620	1													250+10	10	41 32.367	81 39.470

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
621								1						250+15	15	41 32.367	81 39.470
622	1													250+15	10	41 32.367	81 39.469
623	1													250+15	38		
624			1											250+20	38	41 32.367	81 39.470
625			1											250+00	10	41 32.364	81 39.473
626	1													250+05	20	41 32.367	81 39.471
627			1											250+05	30	41 32.366	81 39.471
628	1													250+10	30	41 32.368	81 39.469
629			1											250+05	38	41 32.366	81 39.472
630	1													250+15	38	41 32.366	81 39.472
631	1													249+90	10	41 32.364	81 39.474
632	1													249+95	15	41 32.364	81 39.473
633			1											249+80	25	41 32.363	81 39.478
634			1											249+85	38		
635						1								249+80	38	41 32.364	81 39.479
636	1													249+85	38	41 32.364	81 39.477
637			1											249+65	30	41 32.361	81 39.480
638													1	249+60	30	41 32.360	81 39.481
639	1													249+60	30	41 32.361	81 39.482
640	1													249+55	38	41 32.361	81 39.482
641			1											249+55	25	41 32.361	81 39.483
642		1												249+55	25	41 32.360	81 39.481
643			1											249+50	20	41 32.360	81 39.483

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
644			1											249+45	25	41 32.358	81 39.484
645	1													249+45	20	41 32.358	81 39.483
646													1	249+50	38	41 32.357	81 39.483
646A						1								249+35	15	41 32.357	81 39.483
646B						1								249+45	38	41 32.358	81 39.484
647	1													249+30	20	41 32.358	81 39.485
648	1													249+25	5	41 32.356	81 39.485
649	1							2						249+25	20	41 32.358	81 39.487
650						1								249+20	38	41 32.358	81 39.488
651						1								249+15	38	41 32.357	81 39.489
652			1											249+10	30	41 32.355	81 39.492
653						1								249+15	25	41 32.354	81 39.492
654								1						248+85	38	41 32.355	81 39.493
655	1					1								247+25	38	41 32.337	81 39.522
656								1						248+85	25	41 32.352	81 39.493
657	1							1						248+85	30	41 32.353	81 39.494
658	1													248+75	20	41 32.353	81 39.495
659								2						248+65	15	41 32.350	81 39.498
660	1													248+65	25	41 32.351	81 39.498
661	1													248+65	38	41 32.351	81 39.498
662	1													248+65	25	41 32.351	81 39.499
663	1													248+60	15	41 32.350	81 39.499
664				1										248+50	15	41 32.350	81 39.499

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
665	1													248+55	25	41 32.351	81 39.500
666								1						248+50	25	41 32.350	81 39.500
667	1													248+40	38	41 32.349	81 39.502
668						1								248+35	25	41 32.349	81 39.502
669			1						1					248+25	25	41 32.348	81 39.503
670			1											248+30	5	41 32.347	81 39.501
671		1												248+10	25	41 32.346	81 39.504
672		1												248+00	38	41 32.346	81 39.505
673														247+95	38		
674	1													248+00	25	41 32.345	81 39.507
675			1											247+95	20	41 32.345	81 39.510
676	1													248+00	20	41 32.345	81 39.509
677								2						247+90	30	41 32.344	81 39.509
678																	
679	1													247+80	25	41 32.344	81 39.511
680			1											247+80	38	41 32.344	81 39.509
681	1													247+65	15	41 32.341	81 39.514
682				1										247+60	20	41 32.341	81 39.516
683										1				247+60	25	41 32.341	81 39.516
684									1					247+55	38	41 32.341	81 39.516
685	1					1								247+50	30	41 32.341	81 39.517
686			1											247+50	38	41 32.341	81 39.518
687								2						247+50	30	41 32.340	81 39.518

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
688								1						247+45	30	41 32.340	81 39.519
689						1								247+40	25	41 32.339	81 39.520
690		1												247+45	38	41 32.339	81 39.519
691	1													247+40	38	41 32.339	81 39.520
692	1													247+30	30	41 32.339	81 39.521
693			1											247+30	20	41 32.338	81 39.521
694	1													247+25	15	41 32.338	81 39.521
695				1										247+25	0	41 32.336	81 39.519
696	1													247+25	30	41 32.338	81 39.522
697	1													247+20	25	41 32.337	81 39.523
698	1													247+10	30	41 32.337	81 39.524
699	1													247+10	38	41 32.336	81 39.525
700						1								247+05	25	41 32.335	81 39.525
701		1												247+00	5	41 32.335	81 39.525
702			1											246+90	20	41 32.336	81 39.523
703	1													246+85	20	41 32.335	81 39.524
704	1													246+65	25	41 32.332	81 39.532
705			1											246+65	25	41 32.332	81 39.532
706	1													246+55	20	41 32.330	81 39.534
707		1												246+55	25	41 32.330	81 39.536
707A	1													246+55	0	41 32.327	81 39.532
708			1											246+40	10	41 32.327	81 39.535
709								1						246+30	20	41 32.329	81 39.538

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
710			1			1								246+35	38	41 32.329	81 39.538
711	1													246+30	15	41 32.327	81 39.536
712			1											246+25	15	41 32.328	81 39.536
713								1						246+20	10	41 32.327	81 39.537
714			1											246+20	20	41 32.327	81 39.539
715	1													246+15	20	41 32.326	81 39.542
716			1											246+10	20	41 32.326	81 39.543
717	1													246+05	20	41 32.325	81 39.543
718	1													246+05	20	41 32.325	81 39.543
719			1											246+05	25	41 32.325	81 39.543
720						1								246+00	20	41 32.324	81 39.544
721			1											246+00	0	41 32.323	81 39.543
722						1								245+95	15	41 32.324	81 39.543
723						1								245+95	38	41 32.325	81 39.546
724				1										245+85	38	41 32.324	81 39.547
724A						1		1						245+90	-10	41 32.321	81 39.544
725	1													245+70	25	41 32.321	81 39.550
726			1											245+80	5	41 32.322	81 39.547
727	1													245+45	38	41 32.321	81 39.553
728			1			1								245+55	38	41 32.323	81 39.553
729	1													245+40	25	41 32.320	81 39.553
730	1													245+40	38	41 32.320	81 39.554
731	1													245+35	25	41 32.319	81 39.555

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
732	1													245+35	38	41 32.320	81 39.556
733	1							1						245+30	30	41 32.320	81 39.556
733A						1								245+30	30	41 32.319	81 39.556
734																	
735								1						245+25	20	41 32.320	81 39.558
736			1											245+25	38	41 32.319	81 39.556
737			1											245+20	5	41 32.316	81 39.557
738			1					1						245+15	15	41 32.316	81 39.558
739	1													245+10	15	41 32.315	81 39.559
740	1													245+05	5	41 32.315	81 39.560
741	1													244+95	20	41 32.315	81 39.562
742	1													244+85	15	41 32.314	81 39.565
742A		1												244+80	0	41 32.312	81 39.564
743								1						244+75	20	41 32.312	81 39.566
744									1					244+75	20	41 32.312	81 39.567
745								1						244+55	38	41 32.311	81 39.570
746			1											244+45	30	41 32.310	81 39.571
747	1													244+45	20	41 32.309	81 39.572
748								1						244+45	15	41 32.309	81 39.571
749								1						244+40	15	41 32.309	81 39.572
750	1													244+40	10	41 32.308	81 39.572
750A	1													244+55	10	41 32.309	81 39.569
751				1										244+30	10	41 32.307	81 39.573

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
752	1													244+25	20	41 32.308	81 39.574
753	1													244+20	10	41 32.306	81 39.575
754	1													244+20	15	41 32.306	81 39.576
755			1											244+20	25	41 32.306	81 39.577
756			1											244+20	20	41 32.306	81 39.577
757	1													244+25	38	41 32.308	81 39.577
758	1													244+20	38	41 32.307	81 39.577
759	1													244+15	38	41 32.307	81 39.577
759A			1											244+25	15	41 32.306	81 39.576
760	1													244+00	15	41 32.304	81 39.580
761	1													243+95	20	41 32.304	81 39.581
762			1											244+00	38	41 32.305	81 39.581
763			1											243+90	15	41 32.303	81 39.582
764									1					243+85	15	41 32.302	81 39.583
765			1											243+80	20	41 32.303	81 39.584
766	1													243+75	15	41 32.302	81 39.584
767			1											243+70	20	41 32.301	81 39.585
768	1													243+65	15	41 32.301	81 39.585
769																	
770						1								243+75	38	41 32.303	81 39.585
771								1						243+65	25	41 32.302	81 39.587
772	1													243+55	38	41 32.300	81 39.588
773						1								243+50	38	41 32.301	81 39.589

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
774	1													243+40	38	41 32.301	81 39.591
775		1												243+35	38	41 32.299	81 39.593
776	1													243+30	38	41 32.299	81 39.593
777	1													243+30	38	41 32.299	81 39.593
778	1													243+05	20	41 32.296	81 39.596
779								1						243+00	38	41 32.296	81 39.597
780	1													243+05	10	41 32.295	81 39.596
781			1											242+95	10	41 32.294	81 39.597
782	1													242+95	25	41 32.295	81 39.598
783		1												243+00	25	41 32.295	81 39.599
784	1													242+95	38	41 32.295	81 39.598
785			1											242+85	10	41 32.293	81 39.598
786							1							242+85	38	41 32.294	81 39.600
787			1											242+75	5	41 32.291	81 39.600
788	1													242+75	25	41 32.292	81 39.603
789						1								242+70	38	41 32.292	81 39.603
790			1											242+65	25	41 32.292	81 39.601
791	1													242+65	25	41 32.292	81 39.603
792								1						242+65	10	41 32.290	81 39.603
792A								1						242+60	20	41 32.290	81 39.605
793	1													242+55	38	41 32.291	81 39.605
794								1						242+55	15	41 32.290	81 39.605
795								1						242+40	25	41 32.291	81 39.608

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
796	1													242+35	25	41 32.289	81 39.610
797								2						242+35	20	41 32.289	81 39.609
798	1													242+35	15	41 32.288	81 39.609
799			1											242+35	10	41 32.287	81 39.608
800						1								242+30	5	41 32.286	81 39.607
800A						1								242+35	5	41 32.287	81 39.607
801			1											242+25	15	41 32.286	81 39.610
802	1													242+25	20	41 32.287	81 39.610
803								1						242+25	38	41 32.287	81 39.610
804			1											242+20	20	41 32.286	81 39.610
805	1													242+15	10	41 32.286	81 39.610
806	1													242+20	38	41 32.285	81 39.611
807			1											242+15	20	41 32.286	81 39.612
808	1							1					1	242+15	25	41 32.286	81 39.612
809			1											242+00	20	41 32.286	81 39.612
810			1											242+00	15	41 32.286	81 39.611
811													1	242+00	15	41 32.285	81 39.613
812								1						241+90	15	41 32.285	81 39.615
812A								1						241+90	38	41 32.284	81 39.617
813	1													241+85	20	41 32.285	81 39.614
814	1													241+80	20	41 32.284	81 39.617
815			1											241+80	20	41 32.284	81 39.617
816			1			1								241+75	20	41 32.283	81 39.618

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
817			1											241+75	15	41 32.283	81 39.617
818	1													241+70	0	41 32.280	81 39.618
819								1						241+70	5	41 32.282	81 39.618
820								1						241+65	0	41 32.280	81 39.619
821	1													241+50	25	41 32.281	81 39.624
821A	1													241+45	38	41 32.281	81 39.624
822	1													241+40	38	41 32.281	81 39.625
823			1											241+30	25	41 32.279	81 39.625
824			1											241+25	20	41 32.279	81 39.626
825								1						241+20	20	41 32.279	81 39.626
826				1										241+20	20	41 32.278	81 39.626
827								1						241+20	38	41 32.279	81 39.627
828													1	241+15	38	41 32.279	81 39.627
829								1						241+40	15	41 32.276	81 39.625
830	1													241+15	38	41 32.277	81 39.628
831								1						241+15	38	41 32.277	81 39.628
832			1											241+05	25	41 32.276	81 39.631
833														241+00	20	41 32.274	81 39.631
834		1												240+95	20	41 32.273	81 39.633
835			1											240+85	20	41 32.274	81 39.634
836	1													240+85	15	41 32.273	81 39.634
837	1													240+80	25	41 32.273	81 39.635
838			1											240+75	20	41 32.273	81 39.636

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
839			1											240+80	15	41 32.272	81 39.635
840	1													240+80	15	41 32.272	81 39.635
841			1											240+75	38	41 32.272	81 39.637
842			1											240+65	20	41 32.271	81 39.638
843						1								240+55	15	41 32.270	81 39.639
844	1													240+55	38	41 32.271	81 39.639
845								2						240+50	15	41 32.269	81 39.640
846								1						240+50	15	41 32.269	81 39.641
846A						1								240+55	25	41 32.270	81 39.640
847								1						240+50	38	41 32.267	81 39.643
848								1						240+40	20	41 32.268	81 39.643
849	1													240+35	25	41 32.268	81 39.644
850	1													240+35	20	41 32.268	81 39.643
851			1			1								240+25	15	41 32.267	81 39.644
852								1						240+25	10	41 32.267	81 39.646
853	1													240+25	38	41 32.268	81 39.646
853A							1							240+15	38	41 32.266	81 39.646
853B	1													240+20	25	41 32.267	81 39.646
854			2											240+15	25	41 32.266	81 39.648
855								1						239+90	25	41 32.264	81 39.651
856								1						239+90	25	41 32.265	81 39.651
857								1						239+90	5	41 32.266	81 39.643
858								1						239+50	5	41 32.259	81 39.656

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
859								1						239+40	38	41 32.260	81 39.658
860	1													239+35	15	41 32.258	81 39.659
861			1											239+45	38	41 32.260	81 39.659
862								1						239+40	25	41 32.259	81 39.661
863													1	239+40	38	41 32.259	81 39.662
864				1										239+25	20	41 32.258	81 39.662
864A				1										239+30	15	41 32.259	81 39.661
865						1								239+15	38	41 32.256	81 39.663
866						1								239+05	15	41 32.255	81 39.666
866A						1								239+05	20	41 32.256	81 39.665
867								1						238+95	20	41 32.254	81 39.667
868								1						238+90	25	41 32.254	81 39.667
869			1											238+90	30	41 32.254	81 39.669
870	1													238+90	30	41 32.255	81 39.669
871			1											238+85	25	41 32.254	81 39.671
872								1						238+75	38	41 32.253	81 39.670
873	1													238+80	15	41 32.253	81 39.671
874								1						238+80	38	41 32.254	81 39.671
875			1											238+75	25	41 32.253	81 39.671
876			1											238+65	25	41 32.252	81 39.674
877			1			1								238+60	38	41 32.252	81 39.675
878								1						238+55	25	41 32.252	81 39.676
879			1											238+55	20	41 32.251	81 39.676

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
880								1						238+40	25	41 32.251	81 39.677
881			1											238+40	20	41 32.251	81 39.676
882																	
883	1								1					238+50	20	41 32.250	81 39.677
884			1			1								238+45	20	41 32.250	81 39.678
885				1										238+40	38	41 32.250	81 39.678
886														238+35	25	41 32.250	81 39.679
887																	
888			1			1								238+30	25	41 32.249	81 39.680
889								1						238+35	-5	41 32.246	81 39.678
890	1													238+15	15	41 32.247	81 39.682
891	1													238+25	38	41 32.248	81 39.682
892	1													238+00	25	41 32.246	81 39.685
893	1													237+90	20	41 32.245	81 39.687
894			1											237+85	25	41 32.245	81 39.687
895	1													237+90	25	41 32.244	81 39.688
896	1													237+80	20	41 32.244	81 39.688
897	1													237+80	38	41 32.244	81 39.689
898				1				1						237+65	38	41 32.242	81 39.691
899	1					1								237+70	30	41 32.243	81 39.691
900			1											225+80	20	41 32.241	81 39.694
901								1						225+80	20	41 32.239	81 39.695
902	1													237+45	20	41 32.239	81 39.694

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
903								1						237+45	20	41 32.240	81 39.694
904	1													237+40	0	41 32.237	81 39.696
905	1													237+30	-5	41 32.236	81 39.696
906						1								237+30	38	41 32.239	81 39.698
906A			1											237+30	20	41 32.239	81 39.698
907						1		2						237+30	38	41 32.238	81 39.698
908	1													237+20	20	41 32.236	81 39.700
909	1													237+20	38	41 32.237	81 39.700
910	1													237+20	38	41 32.238	81 39.700
911			1											237+15	20	41 32.236	81 39.701
912								1						237+15	38	41 32.236	81 39.700
912A						1								237+15	25	41 32.237	81 39.702
913	1							1						237+00	20	41 32.234	81 39.703
914	1													237+00	20	41 32.235	81 39.703
915	1													236+95	20	41 32.235	81 39.703
916								1						236+90	38	41 32.235	81 39.704
917			1											236+90	20	41 32.235	81 39.704
918			1											236+85	20	41 32.235	81 39.705
919						1								236+80	20	41 32.234	81 39.705
920	1													236+80	25	41 32.233	81 39.706
921	1													236+80	38	41 32.234	81 39.706
922			1											236+75	38	41 32.233	81 39.706
923	1													236+75	15	41 32.233	81 39.707

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
924			1											236+75	0	41 32.231	81 39.704
925								1						236+60	20	41 32.231	81 39.707
926								1						236+65	20	41 32.232	81 39.708
927														237+25	15	41 32.237	81 39.697
927A	1													236+55	38	41 32.231	81 39.708
928	1													236+55	20	41 32.232	81 39.707
929	1													236+50	15	41 32.230	81 39.711
930	1													236+50	20	41 32.230	81 39.711
931		1												236+50	20	41 32.231	81 39.711
932	1							1						236+40	20	41 32.230	81 39.712
933	1													236+45	25	41 32.231	81 39.710
934			1			1								236+55	38	41 32.231	81 39.710
935						1								236+45	38	41 32.230	81 39.712
936	1													236+40	25	41 32.230	81 39.712
937			1											236+35	20	41 32.229	81 39.713
938	1													236+30	25	41 32.229	81 39.714
939						1		2						236+30	38	41 32.229	81 39.714
940						1								236+30	38	41 32.229	81 39.713
941	1													236+30	20	41 32.228	81 39.714
942						1								236+05	38	41 32.227	81 39.718
943					1	1								236+05	5	41 32.225	81 39.718
944			1											236+00	20	41 32.226	81 39.719
945	1							1						235+95	15	41 32.225	81 39.720

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
946			1											235+90	0	41 32.222	81 39.720
947			1											235+85	-5	41 32.221	81 39.720
948	1													235+80	20	41 32.223	81 39.724
949								1						235+80	25	41 32.224	81 39.725
950								1						235+80	20	41 32.224	81 39.724
951								1						235+75	20	41 32.223	81 39.725
952			1											235+70	20	41 32.223	81 39.726
953				1										235+70	38	41 32.223	81 39.726
953A	1													235+65	20	41 32.222	81 39.726
954			1											235+65	15	41 32.221	81 39.726
955			1											235+60	15	41 32.221	81 39.727
955A													1	235+60	38	41 32.221	81 39.726
956			1											235+60	0	41 32.220	81 39.726
957								1						235+55	5	41 32.221	81 39.726
958		1												235+50	20	41 32.221	81 39.728
959														235+50	20	41 32.221	81 39.729
960						1								235+50	20	41 32.220	81 39.729
961								1						235+40	20	41 32.220	81 39.729
962								1						235+40	20	41 32.220	81 39.730
963								1						235+15	15	41 32.216	81 39.734
964			1											235+10	5	41 32.215	81 39.735
965			1											235+10	20	41 32.217	81 39.735
966	1													235+10	38	41 32.218	81 39.734

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
967						1								235+05	38	41 32.218	81 39.735
968								1						235+00	38	41 32.217	81 39.736
968A										1				235+15	20	41 32.217	81 39.733
969	1							1						235+05	10	41 32.215	81 39.736
970			1											234+85	5	41 32.213	81 39.738
971									1					234+90	15	41 32.214	81 39.738
972			1											234+80	15	41 32.213	81 39.739
973			1											234+80	20	41 32.212	81 39.743
974			1											234+75	38	41 32.214	81 39.742
975								1						234+80	20	41 32.213	81 39.741
976	1													234+60	15	41 32.212	81 39.744
977			1					1						234+60	20	41 32.212	81 39.743
978						1								234+60	10	41 32.211	81 39.743
979			1											234+55	0	41 32.209	81 39.745
980					1									234+50	15	41 32.210	81 39.745
980A										1				234+45	0	41 32.208	81 39.745
981			1											234+25	5	41 32.207	81 39.750
982		1												234+25	15	41 32.207	81 39.751
983								2						234+30	10	41 32.207	81 39.749
984													1	234+25	38	41 32.208	81 39.752
985			1											234+25	20	41 32.210	81 39.751
986			1			1								234+30	38	41 32.208	81 39.750
986A								1						234+20	38	41 32.209	81 39.752

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
987	1													234+15	20	41 32.207	81 39.754
987A								1						234+00	38	41 32.207	81 39.755
987B	1													233+95	38	41 32.206	81 39.755
987C								1						234+00	15	41 32.204	81 39.755
988			1											233+90	0	41 32.202	81 39.755
989								1						233+90	0	41 32.201	81 39.755
990			1											233+80	5	41 32.202	81 39.755
991						1								233+80	15	41 32.204	81 39.757
992						1								233+75	15	41 32.203	81 39.758
993						1								233+75	15	41 32.203	81 39.758
994			1											233+60	20	41 32.202	81 39.762
994A					1					1				233+65	10	41 32.201	81 39.760
995			1											233+55	15	41 32.201	81 39.763
996			1			1								233+35	10	41 32.199	81 39.765
997	1					1								233+35	10	41 32.197	81 39.766
998	1													233+30	20	41 32.199	81 39.766
999	1					1								233+60	-5	41 32.199	81 39.767
999A										1				233+30	38		
1000								1						233+20	5	41 32.196	81 39.769
1001			1											233+25	15	41 32.198	81 39.768
1001A			1											233+25	10	41 32.197	81 39.767
1002								1						233+20	25	41 32.199	81 39.769
1003	1													233+10	25	41 32.196	81 39.772

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
1003A								1						233+10	38	41 32.197	81 39.771
1004				1										233+00	15	41 32.196	81 39.773
1005			1											233+00	20	41 32.196	81 39.774
1006	1													233+05	15	41 32.195	81 39.772
1007				1		1								232+85	10	41 32.193	81 39.775
1008						1		1						232+85	10	41 32.193	81 39.774
1009				1										232+85	20	41 32.194	81 39.775
1010	1													232+85	15	41 32.194	81 39.775
1011																	
1012			1											232+80	20	41 32.194	81 39.776
1013	1													232+75	20	41 32.194	81 39.776
1014					1									232+75	25	41 32.194	81 39.777
1015								1						232+70	5	41 32.191	81 39.777
1016	1					1								232+65	5	41 32.191	81 39.777
1017								1						232+65	0	41 32.190	81 39.777
1018			1			1								232+65	0	41 32.190	81 39.779
1019								2						232+60	0	41 32.189	81 39.779
1020			1											232+55	10	41 32.190	81 39.780
1021						1								232+50	5	41 32.190	81 39.779
1022	1													232+75	25	41 32.193	81 39.777
1023								2						232+50	38	41 32.192	81 39.783
1024								2						232+50	20	41 32.191	81 39.783
1025								1						232+40	15	41 32.189	81 39.783

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
1026			1											232+50	5	41 32.190	81 39.779
1027		1												232+40	5	41 32.188	81 39.783
1028		1												232+40	15	41 32.188	81 39.784
1029			1											232+30	38	41 53.648	81 66.31
1030				1				1						232+30	20	41 53.648	81 66.310
1030A			2											232+25	25	41 53.647	81 66.312
1031			1											232+30	15	41 53.647	81 66.307
1032			1											232+25	20	41 53.645	81 66.312
1033	1													232+25	15	41 53.645	81 66.31
1034	1													232+15	15	41 53.643	81 66.313
1035					1									232+15	15	41 53.643	81 66.313
1036													1	232+20	38	41 53.648	81 66.312
1037													1	232+15	38	41 53.645	81 66.313
1038													1	232+10	38	41 53.645	81 66.313
1039													1	232+05	38		
1040								1						232+05	20	41 53.642	81 66.318
1041												1		231+95	15	41 53.64	81 66.32
1042			1											231+95	10	41 53.638	81 66.318
1043								1						231+80	10	41 53.637	81 66.322
1044	1													231+80	20	41 53.64	81 66.325
1045								1						231+60	15	41 53.633	81 66.33
1046						1								231+65	20	41 53.638	81 66.328
1047	1													231+60	38	41 53.637	81 66.328

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
1048	1													231+50	15	41 53.633	81 66.33
1049								1						234+45	15	41 53.632	81 66.33
1050								1						231+40	15	41 53.632	81 66.335
1051												1		231+40	15	41 53.632	81 66.335
1052	1													231+40	38	41 53.636	81 66.331
1053										1				231+35	15	41 53.63	81 66.333
1054										1				231+35	20	41 53.63	81 66.337
1055								1						231+35	25	41 53.63	81 66.335
1056								1						231+35	15	41 53.632	81 66.335
1057					1									231+30	20	41 53.63	81 66.337
1058	1													231+25	10	41.53.628	81 66.337
1059					1									231+30	25	41 53.317	81 66.338
1060						1								231+35	38	41 53.633	81 66.338
1061	1													231+30	38	41 53.632	81 66.338
1062								1						231+20	38	41 53.632	81 66.338
1063		1												231+25	15	41 53.63	81 66.337
1064														231+25	10	41 53.63	81 66.335
1065	1													231+25	10	41 53.63	81 66.335
1066								1						231+30	15	41 53.63	81 66.332
1067					1	1				1				231+20	10	41 53.627	81 66.337
1068	1													231+10	20	41 53.627	81 66.343
1069			1											231+25	15	41 53.628	81 66.338
1070								2						231+20	15	41 53.628	81 66.34

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
1071	1													231+10	10	41 53.627	81 66.343
1072								1						231+05	38	41 53.63	81 66.347
1073	1					1								231+10	38		
1074	1													231+15	38		
1075	1													231+10	15	41 53.628	81 66.345
1076								2						231+00	10	41 53.625	81 66.347
1077						1								230+90	10	41 53.623	81 66.348
1077A								1				1		230+95	10	41 53.625	81 66.348
1078								1						230+90	10	41 53.623	81 66.348
1079														230+90	38	41 53.627	81 66.348
1079A								1						230+90	20	41 53.625	81 66.35
1080								1						230+80	15	41 53.622	81 66.352
1081								1						230+80	38	41 53.623	81 66.352
1082																	
1083	1													230+75	20	41 53.622	81 66.352
1084	1													230+70	0	41 53.618	81 66.352
1085					1									230+65	5	41 53.618	81 66.357
1086	1													230+70	20	41 53.62	81 66.355
1087								1						230+60	0	41 53.617	81 66.357
1088			1											230+60	5	41 53.617	81 66.357
1089	1													230+55	20	41 53.621	81 66.358
1090				1										230+70	20	41 53.62	81 66.357
1091	1													230+55	5	41 53.617	81 66.358

Dolos Number	Break Type													Location			
	Straight Shank	Straight Mid Shank	Angled Shank	Angled Mid Shank	Cracked Shank	Straight Fluke	Straight Fluke Tip	Angled Fluke	Angled Fluke Tip	Cracked Fluke	Damaged Fluke	Damaged/ Broken Fluke Tip	Pieces	Station Number	Distance from Baseline	GPS North (Decimal degrees)	GPS 38st (Decimal degrees)
1092								1						230+55	15	41 53.613	81 66.363
1093						1								230+45	10	41 53.617	81 66.365
1094			1											230+40	15	41 53.613	81 66.362
1095			1											230+40	15	41 53.613	81 66.362
1096			1											230+35	15	41 53.613	81 66.362
1097										1				230+05	15	41 53.61	81 66.375
1098	1													230+65	0	41 53.618	81 66.357
1098A		1												230+60	15	41 53.62	81 66.357
1099	1													230+65	15	41 53.618	81.664

Appendix B: Broken/Damaged Stone Armor Units (Type of Stone and Breaks) on Burns Harbor North Breakwater, August 2006 Walking Inspection

Stone No.	Station	Approximate Distance from Baseline m (ft)		Type of Stone	Comments
		Lake Side	Harbor Side		
382	Head	1.2 (4)		Dolomite	Split into 2 pieces
380	Head		1.5 (5)	Indiana Bedford Limestone	Split into 3 pieces
381	0+00	1.5 (5)		Dolomite	Split into 2 pieces
379	0+00	0.6 (2)		Granite	Split into 3 pieces
378	0+25		3.05 (10)	Indiana Bedford Limestone	Split into 3 pieces
377	0+25		3.7 (12)	Indiana Bedford Limestone	Split into 3 pieces
376	0+40	8.2 (27)		Granite	Split into 3 pieces
375	0+35	Center Crest		Indiana Bedford Limestone	Split into 2 pieces
374	0+35	Center Crest		Dolomite	Split into 2 pieces
373	0+50		9.8 (32)	Indiana Bedford Limestone	Cracked
372	0+50	3.7 (12)		Indiana Bedford Limestone	Split – in underlayer
371	0+75	9.8 (32)		Indiana Bedford Limestone	Split into multiple pieces – in underlayer
370	0+75		11.3 (37)	Granite	Split into 2 pieces
367	1+00	9.8 (32)		Granite	Split
366	1+00	3.4 (11)		Granite	Split in half
365	1+20		7.6 (25)	Dolomite	Broken corner
363	1+25		4.6 (15)	Indiana Bedford Limestone	Horizontal crack
362	1+40	5.2 (17)		Indiana Bedford Limestone	Split
361	1+75	6.7 (22)		Indiana Bedford Limestone	Split – in underlayer
360	2+00		3.05 (10)	Dolomite	Cracked
359	2+50		6.1 (20)	Dolomite	Highly eroded/split
358	2+50		9.1 (30)	Indiana Bedford Limestone	Split with Horizontal crack
356	3+00	Center Crest		Dolomite	Split
355	3+00		4.6 (15)	Dolomite	Eroded and falling apart
354	3+00	7.0 (23)		Indiana Bedford Limestone	Split – in underlayer

Stone No.	Station	Approximate Distance from Baseline m (ft) Lake Side	Harbor Side	Type of Stone	Comments
353	3+00	4.0 (13)		Granite	Split into 2 pieces
352	3+00	3.4 (11)		Indiana Bedford Limestone	Split in corner
351	3+00	3.4 (11)		Dolomite	Cracked
350	3+00		10.7 (35)	Indiana Bedford Limestone	Split into 2 pieces
349	3+00		11.6 (38)	Indiana Bedford Limestone	Cracked
348	3+30	3.05 (10)		Indiana Bedford Limestone	Split
347	3+25		4.6 (15)	Dolomite	Split into 3 pieces
346	3+25		4.6 (15)	Dolomite	Cracked
345	3+50		4.6 (15)	Dolomite	Pieces
344	3+50	5.5 (18)		Indiana Bedford Limestone	Pieces
343	3+50	4.0 (13)		Granite	Split into 4 pieces - void
342	3+50	Center Crest		Indiana Bedford Limestone	Split into 2 pieces
341	3+50		1.2 (4)	Dolomite	Split into 2 pieces
340	3+50		2.4 (8)	Dolomite	Split into 3 pieces
339	3+75		9.1 (30)	Dolomite	Split
338	3+75		7.6 (25)	Dolomite	Cracked
337	3+75	Center Crest		Dolomite	Split into 3 pieces
336	3+75	8.5 (28)		Indiana Bedford Limestone	Split – in underlayer
335	4+00	1.5 (5)		Indiana Bedford Limestone	Split
331	4+00		10.7 (35)	Dolomite	Split into 2 pieces
330	4+00		1.8 (6)	Dolomite	Cracked
329	4+00	1.8 (6)		Indiana Bedford Limestone	Split into 2 pieces
328	4+00	1.8 (6)		Granite	Split
327	4+50	6.4 (21)		Indiana Bedford Limestone	Split – in underlayer
326	4+50	Center Crest		Dolomite	Split into 2 pieces
325	4+50	2.7 (9)		Indiana Bedford Limestone	Split – in underlayer
324	4+60	1.5 (5)		Granite	Split into 3 pieces
323	4+75	1.5 (5)		Indiana Bedford Limestone	Split into 4 pieces
322	4+75	4.9 (16)		Granite	Split into 2 pieces
321	4+75	3.05 (10)		Dolomite	Split into 2 pieces
320	4+75		5.5 (18)	Quartzite	Split – in underlayer
319	4+80		4.9 (16)	Dolomite	Split
318	4+95	5.8 (19)		Indiana Bedford Limestone	Split into 3 pieces – in underlayer

Stone No.	Station	Approximate Distance from Baseline m (ft)		Type of Stone	Comments
		Lake Side	Harbor Side		
317	5+10		6.1(20)	Dolomite	Split
316	5+00	4.6 (15)		Indiana Bedford Limestone	Split into 3 pieces – in underlayer
315	5+00	7.6 (25)		Granite	Cracked
314	5+20		7.6 (25)	Indiana Bedford Limestone	Broken corner
313	5+10	3.05 (10)		Granite	Cracked
311	5+75	3.05 (10)		Granite	Split
308	6+00	8.2 (27)		Granite	Split and cracked
307	6+25		5.2 (17)	Dolomite	Pieces
306	6+35	3.05 (10)		Granite	Split into 2 pieces
305	6+50	3.7 (12)		Granite	Split into 3 pieces
304	6+50	4.3 (14)		Granite	Split into 2 pieces
303	6+50	4.9 (16)		Granite	Corner split in 4 pieces
302	7+00		5.2 (17)	Quartzite	Fractured into 3 pieces
301	7+00	3.05 (10)		Dolomite	Split into multiple pieces
300	7+50	3.05 (10)		Indiana Bedford Limestone	Split
299	7+75	3.7 (12)		Indiana Bedford Limestone	Split
298	7+85		4.3 (14)	Indiana Bedford Limestone	Split – in underlayer
297	7+85	3.05 (10)		Dolomite	Split
296	8+20	3.05 (10)		Indiana Bedford Limestone	Split
295	8+50	3.05 (10)		Dolomite	Split into 2 pieces
294	8+50	7.6 (25)		Dolomite	Pieces
293	8+50	6.1 (20)		Dolomite	Pieces
292	8+50		3.05 (10)	Indiana Bedford Limestone	Bottom cracked off
291	8+75		2.4 (8)	Granite	2 pieces broken off
290	9+00	6.1 (20)		Indiana Bedford Limestone	Split into 3 pieces – in underlayer
288	9+60	4.6 (15)		Indiana Bedford Limestone	Split
287	9+85	4.3 (14)		Dolomite	Split
286	10+05	3.05 (10)		Dolomite	Split
285	10+75		4.6 (15)	Granite	Split into 2 pieces
284	11+20		10.7 (35)	Indiana Bedford Limestone	Split – edge of water
283	10+90		1.5 (5)	Dolomite	Fractured
282	11+00	3.05 (10)		Dolomite	Cracked

Stone No.	Station	Approximate Distance from Baseline m (ft)		Type of Stone	Comments
		Lake Side	Harbor Side		
281	12+00	3.7 (12)		Indiana Bedford Limestone	Multiple fractures
280	12+15	10.7 (35)		Indiana Bedford Limestone	Split – edge of water
279	12+25		3.7 (12)	Indiana Bedford Limestone	Cracked
278	12+50	6.1 (20)		Indiana Bedford Limestone	Split into 3 pieces – in underlayer
277	12+65	3.05 (10)		Indiana Bedford Limestone	Split
276	13+10	4.6 (15)		Indiana Bedford Limestone	Split into 5 pieces
275	12+85	1.8 (6)		Dolomite	Split and cracked
274	13+25	7.6 (25)		Indiana Bedford Limestone	Split – in underlayer
273	13+60	3.05 (10)		Indiana Bedford Limestone	Split
272	13+80	1.8 (6)		Indiana Bedford Limestone	Split
271	14+00		3.05 (10)	Granite	Split corner
270	14+25	7.6 (25)		Indiana Bedford Limestone	Split
269	14+50	7.6 (25)		Indiana Bedford Limestone	Split
268	14+35		3.7 (12)	Indiana Bedford Limestone	Split – in underlayer
267	15+50		3.7 (12)	Indiana Bedford Limestone	Split – in underlayer
266	15+50		4.3 (14)	Granite	Cracked
265	15+60		3.05 (10)	Granite	Broken corner
264	16+00	Center Crest		Dolomite	Split and cracked
263	16+10	Center Crest		Dolomite	Split into 2 pieces
262	16+10	3.7 (12)		Indiana Bedford Limestone	Split
261	16+10	3.7 (12)		Indiana Bedford Limestone	Split
260	16+40		3.7 (12)	Indiana Bedford Limestone	Cracked
259	16+50	4.9 (16)		Indiana Bedford Limestone	Split – in underlayer
258	16+40		3.05 (10)	Indiana Bedford Limestone	
257	16+50		5.8 (19)	Indiana Bedford Limestone	Split
256	16+60	4.3 (14)		Dolomite	Split
255	16+60	6.7 (22)		Indiana Bedford Limestone	Split
254	16+75	Center Crest		Indiana Bedford Limestone	Split
253	16+90	9.8 (32)		Indiana Bedford Limestone	Split
252	17+50		8.8 (29)	Indiana Bedford Limestone	Split
251	17+50		3.05 (10)	Dolomite	Sliver
250	17+90		3.05 (10)	Indiana Bedford Limestone	Split
249	17+90		3.05 (10)	Indiana Bedford Limestone	Crushed from impact

Stone No.	Station	Approximate Distance from Baseline m (ft)		Type of Stone	Comments
		Lake Side	Harbor Side		
248	17+90		3.05 (10)	Dolomite	Split into 3 pieces – in underlayer
246	18+75		3.05 (10)	Dolomite	Cracked
245	18+75		10.7 (35)	Indiana Bedford Limestone	4x5x3 ft block broken off
244	18+75	5.5 (18)		Indiana Bedford Limestone	Pieces
243	19+50	3.05 (10)		Indiana Bedford Limestone	Split
242	19+50	6.7 (22)		Indiana Bedford Limestone	Split – in underlayer
241	19+50	3.7 (12)		Indiana Bedford Limestone	Split and cracked
240	20+25	Center Crest		Indiana Bedford Limestone	Split down the middle
239	20+25	Center Crest		Indiana Bedford Limestone	Pieces
238	19+80	6.7 (22)		Indiana Bedford Limestone	Split
237	19+90	3.05 (10)		Indiana Bedford Limestone	Split
236	20+00		4.3 (14)	Indiana Bedford Limestone	Split down the grain
235	20+25	3.7 (12)		Indiana Bedford Limestone	Split into 3 pieces
234	21+00		4.3 (14)	Granite	Under #232
233	20+95	3.7 (12)		Indiana Bedford Limestone	Split into 2 pieces – in underlayer
232	21+00		4.3 (14)	Granite	Split into 3 pieces- possibly from impact
231	21+40		7.3 (24)	Granite	6 in. Split from impact
230	21+45	5.2 (17)		Indiana Bedford Limestone	Split – in underlayer
229	21+40		7.3 (24)	Granite	6 in. Split and cracked from impact
228	21+40		3.05 (10)	Indiana Bedford Limestone	Corner split off from impact
227	21+60	3.7 (12)		Indiana Bedford Limestone	Split – in underlayer
226	21+60	3.7 (12)		Indiana Bedford Limestone	Split – in underlayer
225	21+75	3.05 (10)		Indiana Bedford Limestone	Split and cracked
224	21+75	Center Crest		Granite	Cracked on 3 faces
223	22+10	3.7 (12)		Indiana Bedford Limestone	Pieces
222	22+00		3.05 (10)	Dolomite	Corner broken off
221	22+00		2.4 (8)	Indiana Bedford Limestone	Split in half
220	22+25	4.3 (14)		Granite	Split into 3 pieces
219	22+40	4.3 (14)		Indiana Bedford Limestone	Split into 4 pieces
218	22+50		7.3 (24)	Dolomite	2 cubic ft block broken off

Stone No.	Station	Approximate Distance from Baseline m (ft) Lake Side	Harbor Side	Type of Stone	Comments
217	22+75	6.7 (22)		Indiana Bedford Limestone	Split into 3 pieces – in underlayer
216	22+75		4.3 (14)	Granite	Top 1 ft split off
215	23+00	3.05 (10)		Indiana Bedford Limestone	Split
214	23+10		6.7 (22)	Dolomite	Split
213	23+25	6.1 (20)		Dolomite	Split
212	23+30	3.7 (12)		Indiana Bedford Limestone	Split
211	23+40	3.05 (10)		Dolomite	Split
210	23+90	3.7 (12)		Indiana Bedford Limestone	Split
209	24+30	1.5 (5)		Dolomite	Split and pieces
207	24+30	5.2 (17)		Indiana Bedford Limestone	Split – in underlayer
206	24+40		3.7 (12)	Indiana Bedford Limestone	Split
205	24+65		6.1 (20)	Dolomite	Pieces
204	24+65	4.6 (15)		Granite	Split
203	24+65	3.7 (12)		Granite	Split
201	25+00	3.7 (12)		Indiana Bedford Limestone	Cracked
200	25+25	6.7 (22)		Granite	Split
198	25+90	3.4 (11)		Indiana Bedford Limestone	Split
197	26+00		10.4 (34)	Dolomite	Split
196	26+30	1.5 (5)		Dolomite	Split
195	27+00		7.3 (24)	Dolomite	Split and cracked
194	26+90		4.6 (15)	Dolomite	Split
193	27+15	3.05 (10)		Granite	Split
192	27+50	Center Crest		Granite	Cracked
191	27+20	6.7 (22)		Granite	Cracked
190	27+50	6.7 (22)		Indiana Bedford Limestone	Cracked
189	28+35		10.4 (34)	Indiana Bedford Limestone	Split
188	28+60	3.05 (10)		Indiana Bedford Limestone	Split
187	28+75	3.05 (10)		Indiana Bedford Limestone	Split – likely placement
186	29+25		4.3 (14)	Granite	Pieces
185	29+25		5.8 (19)	Granite	Split
184	29+75	6.7 (22)		Indiana Bedford Limestone	Split
183	30+25	4.6 (15)		Indiana Bedford Limestone	Split
182	30+20	4.6 (15)		Dolomite	Split

Stone No.	Station	Approximate Distance from Baseline m (ft)		Type of Stone	Comments
		Lake Side	Harbor Side		
181	30+50		9.1 (30)	Granite	Cracked
180	30+75		4.6 (15)	Limestone –small	Multiple fractures
179	31+10		10.7 (35)	Dolomite	Split with multiple cracks
178	31+10	6.7 (22)		Granite	Pieces
177	31+35		2.4 (8)	Limestone –small	Pieces
175	31+50		3.7 (12)	Limestone –small	Multiple fractures
174	31+50	1.5 (5)		Limestone –small	Split with cracks
173	31+85	Center Crest		Limestone –small	Cracked
172	31+95	3.05 (10)		Limestone –small	Pieces
171	31+95	5.2 (17)		Indiana Bedford Limestone	Split
170	32+00		5.8 (19)	Limestone –small	Split
169	32+10	2.4 (8)		Limestone –small	Multiple cracks
168	32+10	3.05 (10)		Limestone –small	Cracked
167	32+15	6.7 (22)		Indiana Bedford Limestone	Split into 2 pieces
166	31+95		4.6 (15)	Limestone –small	Pieces
164	32+00		3.7 (12)	Limestone –small	Split
163	32+25		7.3 (24)	Limestone –small	Split
162	32+30		10.4 (34)	Limestone –small	Multiple fractures
161	32+30		7.3 (24)	Limestone –small	Multiple fractures
160	32+40		3.05 (10)	Dolomite	Pieces
159	32+40		5.5 (18)	Dolomite	Cracked
158	32+50		4.3 (14)	Dolomite	Split
157	32+60		7.3 (24)	Dolomite	3 broken corners
156	32+75		3.05 (10)	Dolomite	Split
155	32+45	3.7 (12)		Indiana Bedford Limestone	Split
154	33+00	3.05 (10)		Dolomite	Split
153	32+90	2.4 (8)		Indiana Bedford Limestone	Pieces
152	33+00	3.05 (10)		Dolomite	Split
151	33+10	Center Crest		Dolomite	Corner split in underlayer
150	33+00	Center Crest		Dolomite	Multiple fractures
149	32+95	4.6 (15)		Indiana Bedford Limestone	Split into 3 pieces
148	33+00	4.6 (15)		Granite	Cracked
146	33+35	Center Crest		Dolomite	Split

Stone No.	Station	Approximate Distance from Baseline m (ft)		Type of Stone	Comments
		Lake Side	Harbor Side		
145	33+55	3.05 (10)		Dolomite	Split
143	33+75		5.8 (19)	Indiana Bedford Limestone	Split
142	33+65	2.4 (8)		Indiana Bedford Limestone	Multiple cracks
140	34+30		4.3 (14)	Dolomite	Split
139	34+75	4.3 (14)		Dolomite	Split into multiple pieces
138	34+90		1.2 (4)	Dolomite	Split into multiple pieces
137	34+65	3.7 (12)		Indiana Bedford Limestone	Cracked
136	35+00		4.3 (14)	Dolomite	Split
135	35+40		3.05 (10)	Dolomite	Multiple cracks
134	35+40		4.9 (16)	Dolomite	Multiple pieces
133	35+40	4.6 (15)		Granite	Cracked
132	35+45	3.7 (12)		Dolomite	Cracks and split
131	35+85		3.7 (12)	Dolomite	Multiple pieces
130	36+05		10.4 (34)	Dolomite	Split
129	36+00		10.4 (34)	Dolomite	Split
128	36+50	3.05 (10)		Dolomite	Split
125	37+00	3.7 (12)		Indiana Bedford Limestone	Split
124	37+25	2.4 (8)		Indiana Bedford Limestone	Cracked
123	37+50	3.05 (10)		Indiana Bedford Limestone	Split
122	38+00		1.8 (6)	Dolomite	Split
121	38+00		3.7 (12)	Indiana Bedford Limestone	Cracked
120	38+40		3.05 (10)	Indiana Bedford Limestone	Split
119	38+50	2.4 (8)		Indiana Bedford Limestone	Cracked – in underlayer
118	38+60	3.05 (10)		Indiana Bedford Limestone	Pieces – Under granite
117	38+80	Center Crest		Dolomite	Split
116	39+30	1.8 (6)		Dolomite	Split
114	39+70	1.8 (6)		Dolomite	Split
113	40+00		3.7 (12)	Dolomite	Split and cracked
112	40+00		4.9 (16)	Dolomite	Multiple cracks
111	40+50		9.8 (32)	Dolomite	Split
109	41+20		10.4 (34)	Indiana Bedford Limestone	Cracked
108	41+00	3.05 (10)		Indiana Bedford Limestone	Corner split
106	41+25	2.4 (8)		Indiana Bedford Limestone	Split into 5 pieces

Stone No.	Station	Approximate Distance from Baseline m (ft)		Type of Stone	Comments
		Lake Side	Harbor Side		
105	41+45	Center Crest		Indiana Bedford Limestone	Multiple cracks
104	41+65	3.05 (10)		Dolomite	Pieces
103	42+75	2.1 (7)		Indiana Bedford Limestone	Void in bottom of stone
102	42+00		4.3 (14)	Indiana Bedford Limestone	Split
101	42+10		3.05 (10)	Granite	Cracked
100	42+25		3.05 (10)	Indiana Bedford Limestone	Split into 3 pieces
99	42+45		3.05 (10)	Indiana Bedford Limestone	Cracked
98	42+40		3.05 (10)	Indiana Bedford Limestone	Split
97	42+70	3.05 (10)		Indiana Bedford Limestone	Split – corner
96	42+55	3.05 (10)		Indiana Bedford Limestone	Cracked
95	42+75	Center Crest		Indiana Bedford Limestone	Split – in underlayer
93	43+00	6.7 (22)		Indiana Bedford Limestone	Split
92	43+20	6.7 (22)		Granite	Split
90	42+25		2.4 (8)	Indiana Bedford Limestone	Split
89	43+40		3.05 (10)	Granite	Split into 2 pieces
88	43+55	3.05 (10)		Indiana Bedford Limestone	Pieces- directly under 87
87	43+55	2.4 (8)		Indiana Bedford Limestone	Cracked
86	44+10	3.7 (12)		Indiana Bedford Limestone	Split – multiple
85	44+15	2.4 (8)		Indiana Bedford Limestone	Split
84	44+25	4.3 (14)		Indiana Bedford Limestone	Cracked
83	44+45	6.7 (22)		Indiana Bedford Limestone	Split and cracked
82	44+65	4.6 (15)		Indiana Bedford Limestone	Split – small piece
81	45+20	6.7 (22)		Indiana Bedford Limestone	Split
80	45+35	5.2 (17)		Indiana Bedford Limestone	Split
79	45+30	5.2 (17)		Granite	Fractured along blast holes
78	46+00	6.1 (20)		Indiana Bedford Limestone	Split
77	46+35		2.4 (8)	Indiana Bedford Limestone	Corner split off
76	47+00	Center Crest		Indiana Bedford Limestone	Cracked

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14. ABSTRACT (concluded)

Monitoring Completed Navigation Projects (MCNP) Program evaluates the structural and functional performance of existing navigation structures. Under Periodic Inspections, aerial photography, ground-truth surveys, walking inspections, photogrammetry, and lidar elevation data are used to periodically assess the structural conditions of selected structures. A database of these structures is being compiled for asset management and other purposes.

Cleveland Harbor East Breakwater, OH, has sustained extensive damage since its construction in 1915. The Breakwater has had an extensive repair history, including a major rehabilitation in 1979–80 involving the placement of 2-ton dolosse on the lakeward slope and crest of the easterly 4,400 feet (ft). Some failed and were replaced with 4-ton dolosse. Other repairs took place in 1986, 1989, 1991, and 2001 on the nondolos sections.

Burns Harbor North Breakwater, IN, is a 4,640 ft rubble-mound structure constructed in 1969. The Breakwater has required extensive maintenance including the addition of 290 kilotons of stone through 1989. A submerged reef was constructed between 1995 and 1998, 75 ft lakeward of the Breakwater, to reduce wave energy reaching the structure.

Records indicate that 1,128 broken and/or cracked dolosse, and 282 damaged armor stones, were documented during the 2006 Periodic Inspections of Cleveland Harbor East Breakwater and Burns Harbor North Breakwater, respectively. This interim data report contains a precise record of dolos and stone armor damage existing in July 2006 on these structures. A comprehensive analysis and technical report correlating this damage with storm and water level conditions will be published at a later date as subsequent additional field data are obtained at these two Great Lakes breakwaters.